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Sir Patrick Moore, Britain's Mr. Astronomy
Small scopes + webcams = great photos

DON DIXON; INSET: NASA/JPL/SS

ON THE COVER

The Milky Way Galaxy we see on a clear, dark night is the outcome of processes that have been at work during most of the universe's history. To dig into that past, astronomers are turning to open and globular star clusters, using their stars as a way to peel back history's layers. In the end, they hope to find a portrait of an ancient time: the Milky Way's beginnings.

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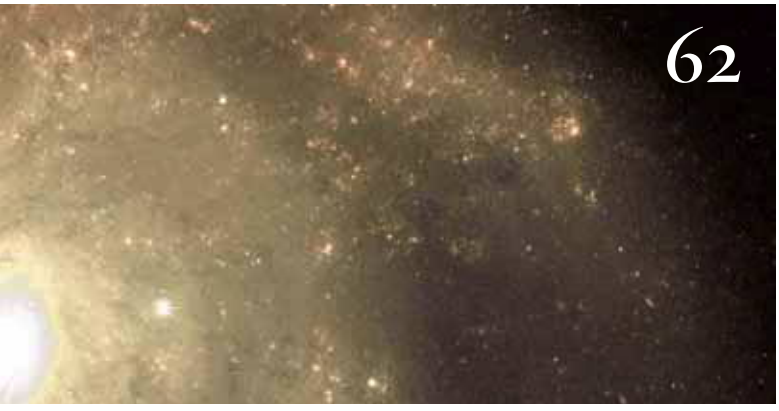

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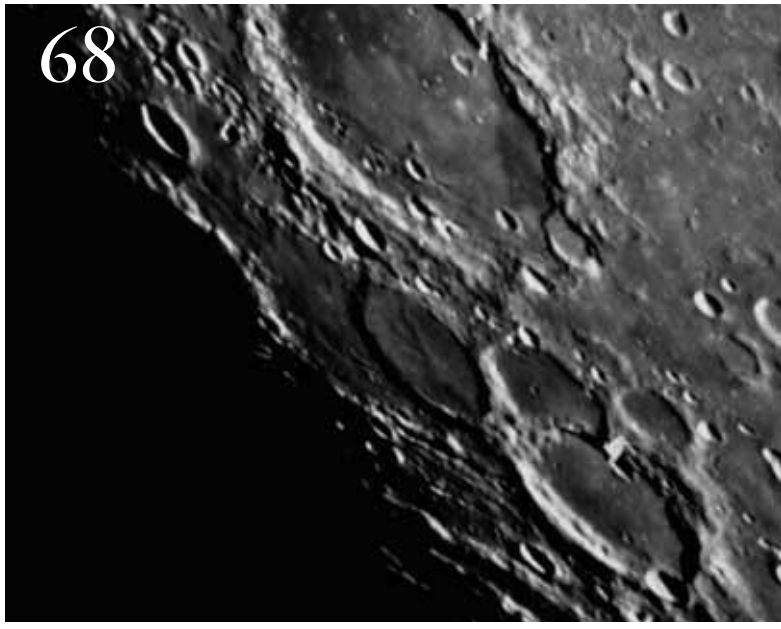

LUNAR AND PLANETARY LABORATORY

JACK NEWTON

BY DAVID J. EICHER

Catching up with Buzz Aldrin

When it comes to the future of space

exploration, few can speak with the authority of Buzz Aldrin. Gemini astronaut, second man on the Moon, and world-famous author and lecturer, Aldrin spreads passion for space exploration everywhere he goes. His rocket-design company, Starcraft Boosters, and the ShareSpace Foundation, a non-profit devoted to space tourism, take much of his time and energy these days. His planned evolving spacecraft, "The Cycler," would shuttle between Earth and Mars. He holds a patent for a space-station design.

Several of *Astronomy*'s editors caught up with Aldrin, 75, in Chicago several months ago. We spent more than 90 minutes talking about the future of space and astronomy, and recorded more than 8,000 words encompassing Aldrin's vision of future human exploration in space. The resulting article, "Space Buzz" (page 40), provides an exclusive look into the future as envisioned by one of the most celebrated explorers in history.

Also, be sure to look at "Stellar archaeology" by Associate Editor Francis Reddy (page 34). In this insightful story, Reddy illuminates a major new finding in the study of our galaxy. For many years, astronomers believed the two types of star clusters, globular and open, were entirely unrelated.

Floating in the distant halo, at the outskirts of the Milky Way Galaxy, globular clusters contain aged, yellow stars in a static, ancient existence. Within the galaxy's disk, open clusters hold bright, vibrant, young blue and white stars that sparkle like gems. Neither had anything to do with the other.

ASTRONOMY: WILLIAM ZUBACK

LIZ KRUESI joins the *Astronomy* staff as an assistant editor.

Recently, however, astronomers have found examples of star clusters that overlap both classifications. These new observations indicate the two types may be related after all, and the findings may reveal secrets of galaxies other than our own.

Closer to home, please join me in welcoming Liz Kruesi as our new assistant editor. Liz graduated from Lawrence University in Appleton, Wisconsin, with a physics major and an English minor.

While studying for her degree, Liz was heavily involved in activities as varied as managing and participating in dance performances, studying astronomy at Columbia University's Biosphere 2 center, and completing two research internships at the University of Chicago. She also serves as Lawrence's Class of 2004 secretary.

After many years of fascination with astronomy, Liz is thrilled to be involved professionally in the field now. We're glad to have such an enthusiastic astronomer as our newest team member.

Yours truly,

David J. Eicher
Editor

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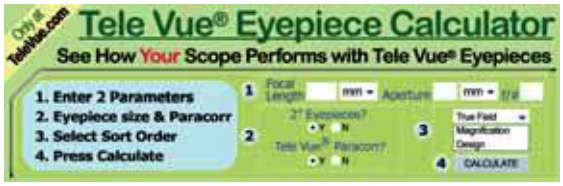

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Going deep in Leo

Thousands of remote galaxies pepper the background in this image of the spiral NGC 3370 in Leo. Adam Riess of the Space Telescope Science Institute observed NGC 3370 with Hubble a dozen times over the course of a month, building this 25-hour exposure. He found several Cepheid variables, stars whose periods of variation are related to their true brightnesses. Comparing the stars' observed brightnesses with their true brightnesses yields their distance. The Cepheids in NGC 3370 — the most distant ever observed — allowed Riess to pin down the galaxy's distance: 98 million light-years.

NASA, THE HUBBLE HERITAGE TEAM, AND A. RIESS (STScI)

A familiar friend

Like other backyard astronomers, I've

invested many hours and resources honing my observing skills while searching for deep-sky objects. Yet, I always return to the one neighbor who sparked my steadfast fascination with astronomy: the Moon. ❨ Robert Burnham's

LUNAR AND PLANETARY LABORATORY

LUNAR CHALLENGES await observers of all experience levels. In the Moon's southern highlands rests a landscape pockmarked with young and ancient impact craters.

"Explore a lunar debris field" (February 2005) reminds me that while Earth's closest companion was most likely the first target we were trained to view, many challenges remain on its surface for experienced skywatchers. I'm sure the next time I observe, I'll take a break from deep-sky objects and target lunar features.
— THOMAS YOUNG, ATHENS, GEORGIA

Nonetheless, merely a human

Concerning "Relativity turns 100" (February 2005), Einstein did not change the cosmos. Instead, he altered how we think about the cosmos. Thanks to humanity's hubris, this was a far greater achievement. — KENNETH C. HEALY, AUBURN HILLS, MICHIGAN

Your use of language in the outstanding articles on Einstein elevates him to the position of a god. While he may be one to the astrophysics community, he was very human. Einstein has not "changed the cosmos forever," nor did he "remake the universe." Your use of language is more akin to a broadsheet than a quality scientific journal. Einstein certainly changed our view of the universe, but he did not change reality.
— ANDREW MARTIN, MELBOURNE, AUSTRALIA

Grasping relativity

I want to thank Richard Panek for his article "Relativity turns 100" (February 2005).

I've long admired Einstein and stand in awe of his genius. I remember Einstein alive, nearly a half-century after his landmark discovery. But until I read this story, I never tried to understand "how Einstein got there."

Now, I am still amazed by relativity but ready to read more. Thank you, Mr. Panek, you helped demystify the greatest discovery of the 20th century for me. — LUCAS E. HARRIS, DREXEL HILL, PENNSYLVANIA

Another must-have

I long for the astronomy gadgets Bob Berman lists (January 2005). Here is one more. A really cool gadget is the "photon cannon." This comes in handy at a star party when people leave their camping lanterns going full throttle. Simply aim a large-aperture Dobsonian at the offending light source, remove the eyepiece, insert a camera flash into the focuser, and POW!

While the light stream is awesome, one always should be careful if the flash victim is bigger than oneself and does not possess a sense of humor. This also is fun to do while waiting for the cloud cover to pass over (assuming you have forgotten your cloud filter). — GEARY KEILMAN, LAS VEGAS

What's in a name?

After reading Bob Berman's column on "Astrospeak" (February 2005), I wondered if most readers know the rich history behind the space shuttles' names.

The space shuttles share titles with great ships of exploration. *Columbia* was the first American vessel to circumnavigate the globe. The British survey ship *Challenger* performed the definitive mapping of the Pacific Ocean.

Atlantis was the Woods Hole Oceanographic Institute's exploration ship. *Discovery* was the name of both Captain Cook's vessel that sailed to the Hawaiian Islands and Henry Hudson's ship that explored the upper North American continent. — JACK HAGERTY, LIVERMORE, CALIFORNIA

We welcome your comments. Send letters to Astronomy *Letters, P.O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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BY BOB BERMAN

Good planets gone bad

After last fall's lunar column ("Glass half empty?" November 2004), I got letters asking why the Moon will be destroyed someday after coming too close to Earth. Good question, and it brings up a new topic: What other weird things will befall our poor planet in the eons to come? ☾ First the Moon. All future strangeness happens because Earth's tidal bulge doesn't sit precisely under the Moon. Our rapid spin pushes the ocean's yard-high surge ahead of the Earth-Moon line. So, the Moon actually pulls backward on this bulge, slowing the Earth's rotation gradually. Earth's day lengthens by ⅕₀₀ of a second per century.

This additional time is not enough for us to meddle with clocks annually, contrary to the leap-second myth. Still, 1 second each 500 centuries does add up. We'll have a 30-hour day in just a billion years. Before you know it, you'll have enough time to call Mom.

Because the Earth-Moon system shares angular momentum, which always is conserved, the Moon receives the energy Earth loses. This boosts the Moon to a higher orbit, currently pushing it 1.25 inches farther away each year. The higher orbit also makes it move slower. Eventually, Earth's rotation and the Moon's revolution will match — both will be 40 days long.

Then, for millions of years, one side of Earth will face the Moon. Half the world will watch the Moon hover above for what seems like forever, while the other half will *never* see it. Who gets the Moon: China or us? No way to know — the continents will have drifted into new patterns by then.

This stable situation is where the story might end, except the Sun has something to say about it, too. Today, the Sun's tidal pull on Earth is only half as strong as the Moon's. But as the Moon departs, the Sun grows relatively more influential.

Ultimately, it makes Earth spin even slower than its new once-a-month rotation. Angular momentum then harasses the Moon again, this time by robbing it of energy. Thus begins the era when the Moon starts falling toward us.

Fortunately for humanity's fate, the Moon will break apart before it reaches 10,000 miles (16,000 kilometers) away because its silicate rocks are only half as dense as Earth's heavier materials.

HALF THE WORLD will watch the Moon hover above for what seems like forever, while the other half will *never* see it. Who gets the Moon: China or us?

Voilà! Earth gets a ring even more glorious than Saturn's. Pencil it in around 3 billion years from now.

Along the way, total solar eclipses will end. In another 60 million years or so, the Moon will appear too small to cover the Sun. And lunar tides, which vary with the *cube* (not square) of the Moon's distance, will become pussycat weak.

Have you seen the tidal bore at Truro in Nova Scotia? From a hilltop, you watch a 2-foot wall of ocean march around a bend and turn the sandy beach below you into a rushing river. Later, it reverses direction. *You gotta see it!* It'll cease in less than a billion years, so don't wait.

Before then, expect the next big asteroid impact. The K-T extinction 65 million years ago wasn't too bad if you're pro-mammal and anti-reptile. But the one before that, 251 million years ago, left only 2 percent of Earth's species intact. Could we fare better than those creepy trilobites? If so, could we handle a planet where only 2 percent of our favorite snacks remain? Supermarkets with nothing but row after row of different brands of kelp?

Say we make it through that. The next challenge comes in 1.1 billion years, when the Sun is 10 percent brighter and the oceans have boiled off. Do we head below ground and wait it out? We could learn from the Canadians, whose amazingly vast labyrinths beneath Toronto and Montreal house rock concerts and restaurants. By then, maybe we'll have emigrated to a planet with lower taxes.

If we stay, things only get worse. In 7 or 8 billion years, the Sun turns into a red giant. Its surface expands beyond Venus' orbit and could venture past us (see Ask Astro, page 66). Although we shouldn't knock something we haven't tried, orbiting *inside* the Sun can't be a great experience.

So off we'll go, bringing stockcar racing to Mars. We load up a spacefaring ark with two of each of Earth's species, except for amoebas, where one is enough.

Hmm, let's see, 90 million species, times 2. No small job. We could save room by leaving mosquitoes and those nervous little dog-breeds behind. Too complicated.

We'll just have to take care of this place now. And "now" is what matters because we — not the Moon — likely will decide if this will be a Paradise Lost. A

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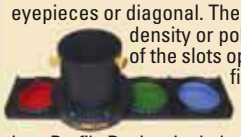

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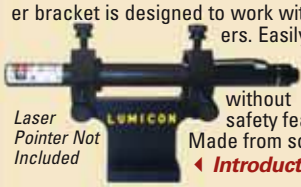

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BY GLENN CHAPLE

Do the hop

One, two — find the star! Three, four

— aim that scope! Five, six … oh, hi. I was practicing the steps to my favorite astronomical dance — the "Star hop." Actually, "star hopping" isn't a dance. It's the way I locate faint, out-of-the-way sky objects with my telescopes — especially my Dobsonian-mounted ones. In a perfect universe, each nebula, cluster, or galaxy would be located next to a naked-eye field star. Center the star in the finder scope, peer into the telescope, and — *voilà!* — near the star is that 10th-magnitude galaxy! In reality, though, you need to consult a star atlas to select the bright star nearest your quarry, as well as dimmer stars bridging the gap between them. With your telescope, you then "star hop" — like a frog across a path of lily pads — from the bright star to your target object.

Star hopping isn't the only way to track down sky objects. Many of today's top-of-the-line telescopes include either setting circles or computerized "go-to" systems to carry you to your target. As useful as setting circles and go-to electronics are, using them is like boarding a tour bus and traveling blindfolded until you arrive at your destination. Think of all the sights you'll miss along the way.

Start hopping

To start hopping, let's explore the galaxy M101, located in Ursa Major (refer to the finder chart on this page). Although listed as magnitude 8, M101 can be difficult for small scopes because its light is spread out over an area roughly two-thirds the Moon's apparent diameter. Save M101 for a clear, dark night.

Our bright guide star is Mizar (Zeta [ζ] Ursae Majoris), which forms the bend in the handle of the Big Dipper. Mizar is a striking telescopic double star worth a telescopic peek before you venture to M101 (see "Double vision," July 2003).

Mizar's naked-eye neighbor Alcor (80 UMa) points to a row of 5th- and 6th-magnitude stars that leads the way to M101. Follow these stellar lily pads either through your finder or the main scope (use low power) until you come to 86 UMa.

The rest of the journey will be made with the main scope, rigged with an eyepiece that covers at least a 1-degree (°) (2 Moon-diameter) field. After you've oriented the finder chart to match what you see through your telescope, star hop your way from 86 UMa to M101. If you spy a faint, circular patch of light in the location shown on the chart, you've found M101!

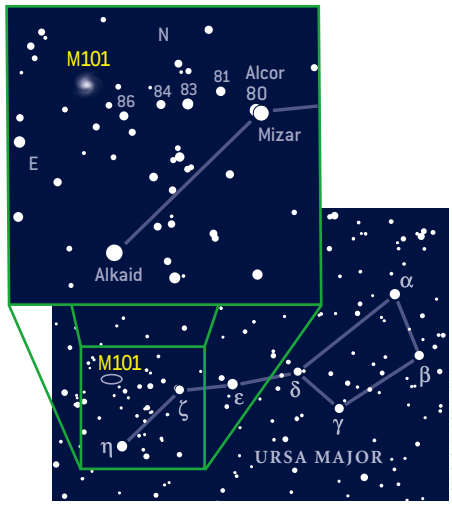
An entry in my astronomy logbook dated May 11, 1977, describes how M101 might appear to the novice using a small-aperture telescope. Having observed M101 for the first time with a 3-inch reflecting telescope, I wrote:

"This galaxy is a 'presence' — a ghost in the field. It would be impossible [to see] in any area near bright lights."

To me, M101 seemed to be 7 or 8 arcminutes (') across (about one-fourth the Moon's apparent diameter) — a fraction of the size suggested by long-exposure photographs. M101 is a face-on spiral galaxy. Peering into the eyepiece, I was looking at light that left M101 some 25 million years ago! Read more about M101 in "A spiral masterpiece" on page 62.

Resources

If you want more information on star hopping, I refer you to the following publications: *A Star Hopper's Guide to the Messier Objects* by Lenore Freeman Morales; *Turn Left at Orion* by Guy Consolmagno and Dan Davis; and *Star-Hopping: Your Vista to Viewing the Universe* by Robert A. Garfinkle. All explain star-hopping techniques and include charts to help you find deep-space wonders easily.



STAR HOP YOUR WAY to M101 across these cosmic lily pads. Start with Mizar. Orient yourself by facing north, then tilt your head back so south is at the top of your view.

In the 35 years I've been an astronomy enthusiast, I've made tens of thousands of telescopic observations. I've observed objects from our Moon, which is 1.3 light-seconds away, to quasars billions of light-years distant.

Anything invisible to the naked eye I found by star hopping. Maybe it isn't a dance, but the "Star hop" makes me feel as though I'm waltzing around the heavens with my telescope.

Next month

Get ready to take a close-up look at our nearest star. I'll talk about how to view the Sun *safely*.

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com.

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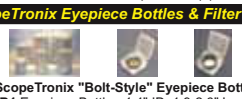

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BY WILLIAM SCHOMAKER

Andrew Gould

Ohio State University astronomer

Andrew Gould isn't afraid of the dark. Rather, he jumps headlong into the shadowy unknown of astronomy's darkest questions. A theorist by training and an observer by necessity, Gould holds court with dim, specter-like objects such as MAssive Compact Halo Objects [MACHOs],

extrasolar planets, failed supernovae, rogue suns, and faint stars. Last year, Gould, a gravitational microlensing expert, and his colleagues accomplished an unprecedented feat: They measured the mass of a tiny star 2,000 light-years away to within 17-percent certainty. How'd they do it? Tenacity, a chance 1993 encounter between two stars, and a little help from gravity.

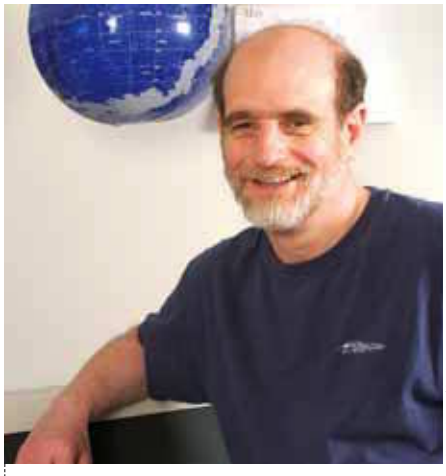
When he's not preparing for the upcoming Space Interferometry Mission (SIM), Gould hunts for extrasolar planets.

What is microlensing, and what was MACHO-LMC-5?

Microlensing involves the rare — and temporary — amplification of a source object's brightness due to gravitational bending of light caused by a foreground lens object (usually something dark and compact) interrupting the line of sight. In a 1992 paper, I showed that if you can measure two key parameters for a microlensing event, then you can get the mass of the lens object. One of those key parameters is the microlensing parallax, not to be confused with the "familiar" trigonometric parallax.

Microlensing parallax measures the size of the event and quantifies how the light curve gets distorted [because] Earth is not traveling in a straight line. The other key parameter is called the angular Einstein radius — also very hard to measure and one of those things you get to measure only in a handful of events.

Throughout the MACHO experiment — which searches for dark matter in the halo of the Milky Way — they expected to find one microlensing event due to a star in the Milky Way passing in front of a source star in the Large Magellanic Cloud. They found one event that occurred in 1993, called MACHO-LMC-5, which gave us an unprecedented opportunity to measure the foreground lensing star's mass.



JOE McCULTY/OHIO STATE UNIVERSITY

ANDREW GOULD refuses to let others think for him. Thinking outside the box helped him measure a single star's mass.

How did you get MACHO-LMC-5's mass?

The first mass measurement for MACHO-LMC-5 was not made by me but [by a team led by] Charles Alcock [director of the Harvard-Smithsonian Center for Astrophysics] in 2001 — although it turns out they got some elements of it wrong. They calculated a distance of 200 parsecs to the lens, and it was clear, from its color and magnitude, it was an M star at 500 or 600 parsecs. This needled a lot of theorists at the time and ultimately led me [to take] a closer look at the problem.

John Bahcall, Chris Flynn [Tuorla Observatory in Finland], and I predicted MACHO would find an event caused by a foreground M star, and they should see the lens and source separately after a period of time. Alcock and his colleagues confirmed this with MACHO-LMC-5. By combining the proper motion and the timescale of the event, they were able to get the angular Einstein radius — [a] key parameter needed to get the mass of the M dwarf lens.

At the time, I was working on a [software] code to determine parallaxes for microlensing events — the other key parameter needed for measuring mass. Other people had written code like this before, but I try to figure out things for myself from first principles — and it's often a waste of time. But in this case, I developed a method that worked from different principles than what people had been using before.

I thought I had better test my code by applying it to MACHO-LMC-5, because it was an event in the literature with parallax. I got a different parallax fit than those guys did, which led to a mass and distance that made sense. My solution had a distance of about 500 parsecs. I thought my code must be wrong. Then I checked it, decided it was right, and figured their code was wrong.

I got together with David Bennett [Notre Dame University] and David Alves [NASA's Goddard Space Flight Center] and collected all the information and got the correct measurements. Still, many different threads, different people's ideas, different experiments and measurements went into this and bubbled up together to make for an unprecedented mass measurement. A

Read more of this interview with Andrew Gould at www.astronomy.com/toc

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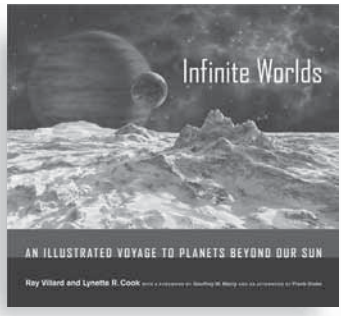
BY RAY VILLARD AND LYNETTE R. COOK

Foreword by Geoffrey W. Marcy
Afterword by Frank Drake



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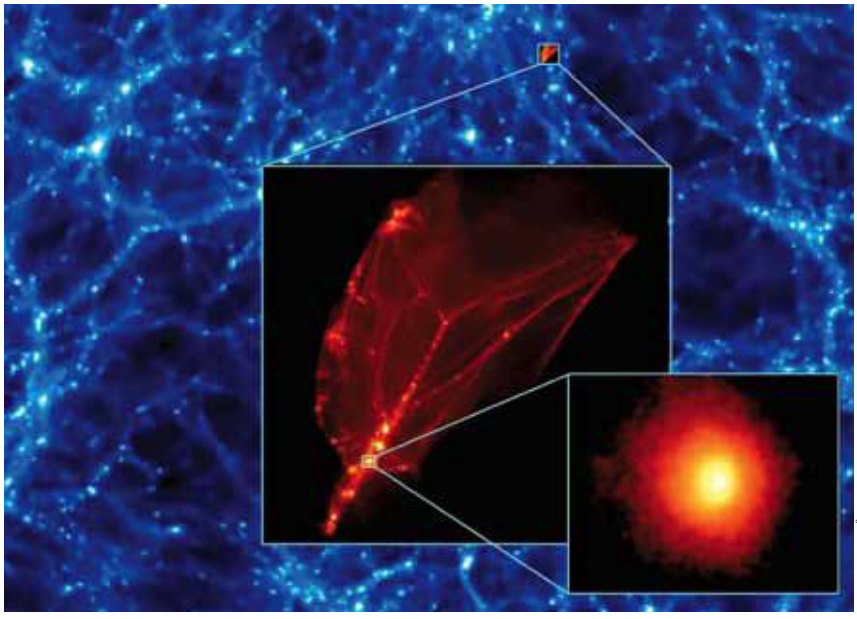
MASSIVE SIDESWIPE. Computer simulations show Pluto and its large moon Charon, which form essentially a double planet, probably resulted from the same kind of giant grazing impact that created Earth and its Moon.

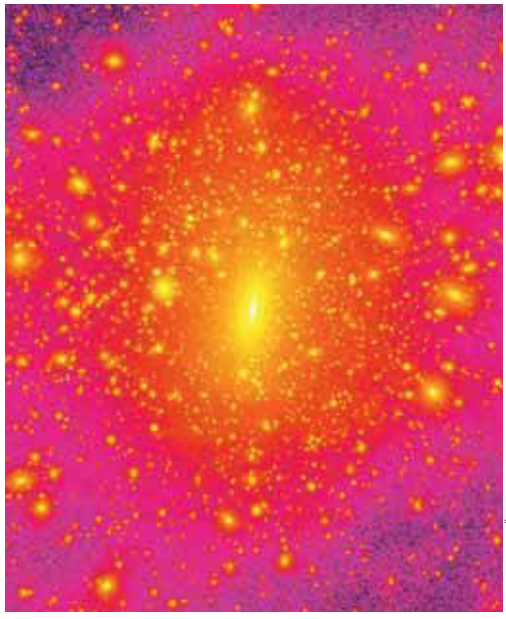
news 05

Tiny extrasolar planet found orbiting a pulsar, diamond layers inside carbon planets, finding some missing matter, and the astronomy of shuttle launches



UNIVERSITY OF ZÜRICH/B. MOORE

COSMIC ZOOM-IN. Large structures grew from dark-matter clumps in the early universe, according to a sophisticated simulation using a new supercomputer.



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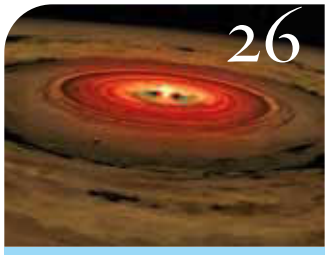
HALO. A 6-month computer run shows Earth-mass clumps of dark matter surrounding the Milky Way.



26 A star fleeing the Milky Way Galaxy

27 Fix HST, or replace it?

30 Gamma-ray bursts and meteorites

32 A stellar dust shell grows and evolves

Cosmic structure began with mini-halos

The first structures to emerge after the Big Bang were solar-system-size clumps of dark matter, say cosmologists at the University of Zürich. Each clump (or "halo") had about 1 Earth mass and appeared 20 million years post-Big Bang.

The scientists used a new supercomputer that allowed calculations on many scales at once. The team's work appears in *Nature* (January 27, 2005).

Cosmologists have long detected small mass-density fluctuations in the cosmic microwave background. They think cosmic structure arose as these fluctuations made dark-matter clumps that attracted ordinary matter. Through gravity, the clumps of material created ever-larger bodies, eventually forming superclusters of galaxies.

Until the Zürich group's finding, scientists thought the first structures to form were galaxy-size clumps of dark matter that evolved into a "haze" of dark-matter particles enveloping a galaxy. However, the group found, "the haze is not smooth, but all the mass is gathered into subclumps," each having about 1 Earth mass.

The cosmologists based their calculations on the leading dark-matter candidate — a weakly interacting massive particle called a neutralino.

They predict about a million billion mini-halos surround our galaxy, with one passing Earth every few thousand years. The most likely way to detect them would be spotting gamma rays created when neutralinos self-annihilate. — LIZ KRUESI

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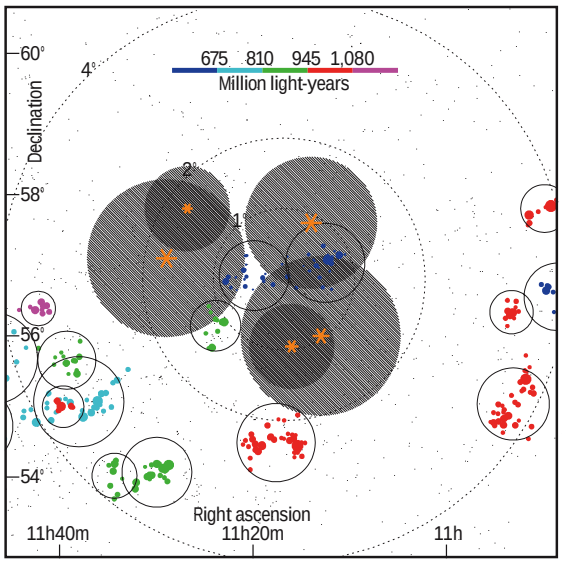
TERRAFORM MARS? Lab experiments show adding synthetic, fluorine-based gases (such as octofluoropropane) to Mars' atmosphere would cause a runaway greenhouse warming by evaporating the carbon-dioxide ice in the polar caps.



NEW YORK UNIVERSITY/G. R. FARRAR, A. A. BERLIND, D. W. HOGG

POWERFUL PARTICLES. Two merging galaxy clusters (center, blue) appear to be showering Earth with ultra-high-energy cosmic rays (orange asterisks). The field lies in Ursa Major.

Cosmic-ray source found

A probable source of ultra-high-energy cosmic rays has been identified, says astrophysicist Glennys Farrar (New York University). The result follows a statistical analysis of data from two cosmic-ray observatories, one in Japan and one in Utah.

Farrar and her coworkers found four ultra-high-energy cosmic rays coming from one point in the sky. The odds of the four being coincidentally aligned, they say, are less than 1 in 100. With a possible position located, Farrar rechecked the data and found a fifth event, at a lower energy, in the same area.

The five high-energy cosmic rays arrived over 10 years from a spot about 3 Full Moons wide centered on 11h17m right ascension and 57° north declination. This lies near the 2nd-magnitude star Merak (Beta [β] Ursae Majoris) in the bowl of the Big Dipper.

The ultra-high-energy cosmic rays, Farrar says, have much higher energies than ordinary cosmic rays. Likely means to kick them up to such energies include a massive star collapsing into a black hole, gamma-ray bursts, and active galactic nuclei (quasars). To look for the source, Farrar turned to the Sloan Digital Sky Survey (SDSS) of galaxies.

"Luckily, the cosmic-ray locations turn out to lie within a Sloan field," says Farrar. The SDSS data suggest the source is two rich clusters of galaxies merging about 550 million light-years away. Farrar says, "In those clusters, there could be obscured active galactic nuclei, there are hints of X-ray sources, and certainly gamma-ray bursts remain possible candidates." — ROBERT BURNHAM

SDSS COLLABORATION

GOING, GOING ... Racing out of the Milky Way, SDSS J090745.0 +24507 (arrow) is fleeing an encounter with a black hole.

Bye-bye, Milky Way

A star is speeding out of the Milky Way with about twice the velocity it needs to keep going forever, says codiscoverer Warren Brown (CfA).

"We've never before seen a star moving fast enough to escape the galaxy," he says.

The star was part of a binary system that sailed too close to a black hole, perhaps the supermassive one at the Milky Way's center. The black hole's gravity snared the companion star and sent this one flying. The finding confirms a theory first proposed in 1998. — MICHAEL E. BAKICH

Do carbon-rich planets have diamond layers?

Extrasolar planets may contain substantial amounts of carbon compounds, says astrophysicist Marc Kuchner (Princeton University). And if they do, he says, they would likely have a diamond layer inside.

"Carbon planets could form much like carbonaceous chondrite meteorites in our solar system," say Kuchner and colleague Sara Seager (Carnegie Institution of Washington).

These meteorites contain carbon compounds such as carbides, graphite, and even tiny diamonds, say the researchers.

Carbon planets would form where oxygen was scarce, notes Kuchner, who adds they can survive closer to a star than silicate planets such as Earth because carbides have high melting points. — R. B.

LYNETTE COOK

DIAMONDS AND TAR. If carbon planets exist, they might have tarry surfaces overlying layers of diamonds.

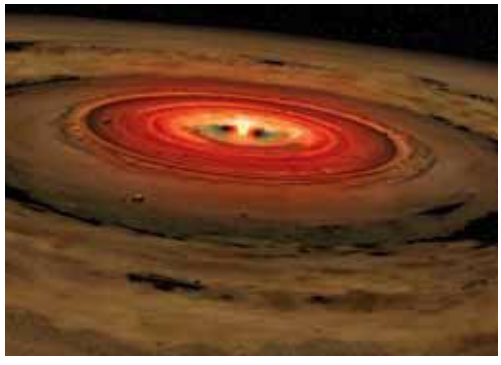
Tiny star has a planet-making disk

A micro-star has the makings of a mini-solar system, says a team of Spitzer Space Telescope astronomers.

The star, a brown dwarf named OTS 44, has the mass of about 15 Jupiters and is surrounded by a dust-rich disk that appears still in the early stages of making planets.

"There may be a host of miniature solar systems with planets orbiting brown dwarfs," says Kevin Luhman (Center for Astrophysics), lead author of the new study, due for publication in *The Astrophysical Journal Letters*.

OTS 44 is about 500 light-years away. Astronomers speculate its disk has enough material to make one gas-giant planet and a handful of Earth-size ones. — R. B



NASA/JPL-CALTECH/T. PYLE

DIM BULB. Hardly bigger than a planet, the star OTS 44 has a disk of dust.

The astronomy of launching a shuttle

Almost 2½ years after the space shuttle Columbia disaster, NASA is set to resume orbital space flight. Discovery will blast off on a long-awaited resupply mission to the International Space Station, a flight that also will include space walks to test techniques of repairing the shuttle's heat protection system.

But the date and time for the shuttle launch is far from arbitrary. And the driving factors are astronomical.

One constraint is the need to reach the space station (as a safe harbor), and that will remain in force from now on. A second constraint involves the need to observe the launch closely to verify the shuttle's safety. The latter constraint will — after several successful missions — be relaxed. And that's a good thing because, taken together, these factors allow only a few days for launch.

The space station is in a low circular orbit, with its plane tilted to Earth's equator by about 52°. Going to the station requires a a shuttle to blast off when the launch site lies directly below the station's orbital path.

This requirement ties the launch time to the station's orbit. If the station's orbit stayed fixed in space, launch windows would recur at the same time daily. But because Earth's equatorial bulge exerts a gravitational tug that continually twists the station's orbital plane westward, the launch window arrives a little earlier each day.

At the altitude and inclination of the space station, the westward movement is about 6° per day. Because Earth spins 360° in one day, it has to spin only 354° to coincide again with the station's orbit, and that takes 24 minutes less than a full day. So the launch window opens 24 minutes earlier every day. After about 60 days, the time is back to where it started.

Now for the second constraint: NASA needs full sunlight at launch to take images that might show insulation flaking off the external fuel tank and damaging the shuttle. And NASA also wants to have full sunlight about half an hour later, when the tank is jettisoned and inspected for missing insulation. By that time, however, the shuttle has gone nearly halfway around the planet. These two factors decree that launches occur near local sunrise, while tank inspections occur before orbital sunset.

NASA

DAWN'S EARLY LIGHT. Astronomical factors decree that Discovery (seen here on STS-102 in March 2001) must launch at sunrise in May or June.

Only a small range of launch times satisfy these requirements. The first date is around May 14, when the tank can be seen just before sunset. Then, for about 20 days, both conditions are satisfied, until the launch time slips earlier than sunrise. Those two dates — roughly May 14 to June 3 — set the window in which the first post-Columbia shuttle launch will be attempted.

The second shuttle launch is targeted for the interval between July 13 and July 31, which duplicates the lighting conditions. Note that this period comes about 60 days later than the first — the result of the daily drift of the space station's orbital plane.

But after the end of July, the constraints really begin to tighten because seasonal trends make the Sun rise later and later. This squeezes the period when both lighting conditions are met, so when the next satisfactory period opens September 9, it lasts only a week, and by the time the following period opens November 7, it's only a few days long.

Things don't get better until the following spring — but by then, mission planners hope a few safe flights will have verified the repairs and eliminated the need for such illumination. Shuttle launches then can occur during a much wider period. — JAMES OBERG

JHU/LOCKHEED MARTIN

HST, VERSION 2.0? A new plan suggests astronomers create a replacement for Hubble based on instruments already built for its upgrade.

Fix Hubble — or replace it?

The Hubble Space Telescope just can't catch a break. In February, NASA's proposed 2006 budget dropped the idea of fixing HST, either by robot or a manned shuttle mission.

Now, an international team led by Johns Hopkins University astronomers suggests creating a new space telescope, the Hubble Origins Probe (HOP), using instruments built for the servicing mission.

HOP would replicate Hubble's original design but use a much lighter mirror and a modern spacecraft frame based on the successful Spitzer Space Telescope.

The new telescope would include two instruments that have been built already — the Cosmic Origins Spectrograph and Wide Field Camera 3. A new camera, dubbed the Very Wide Field Imager, would be built in collaboration with Japanese partners.

The telescope's design also could host one additional instrument, perhaps a spectrograph contributed by European and Australian partners. — FRANCIS REDDY

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All of these refractors are basic optical tubes, with dust covers and a carrying case only. Complete optical tubes, with a star diagonal, Plössl eyepiece, mounting ring, dust covers, and carry case are also available from stock.

As for accessories, we keep them all. Gibraltar, Panoramic, Tele-Pod mounts; Sky Tour computers for those mounts; Nagler, Radian, Panoptic, Plössl eyepieces; Powermates and Barlows; Everbrite 99% reflectivity dielectric star diagonals; light pollution filters; and more. Whatever TeleVue you need, we probably have it in stock.

Does your dealer?

There's nothing mysterious about *this* Sphinx.

Vixen Star Book hand control showing star chart display

Vixen Sphinx telescopes and mounts take the mystery out of go-to astronomy. You don't have to know Messier, NGC, or IC numbers to find things in the sky.

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You can update the Star Book's 4MB flash ROM memory from the Internet to keep you current with the heavens. And the easy-to-use Star Book can be used as a stand-alone star atlas so you can learn the skies anywhere, anytime.

$3250
ED80SWT-SXW 3.1" f/9 ED apo Vixen refractor on Sphinx go-to mount

The Sphinx go-to mount with Star Book controller is available separately for use with your own optics. It is also available in premium Vixen telescope/mount packages that range from a 3.1" refractor to big 8" reflectors and catadioptrics.

Vixen Sphinx details and prices are on our **www.astronomics.com** website.

Meade Deep Sky Imager (DSI) for $299.

The **Meade Deep Sky Imager** takes color deep sky photos at a fraction the cost of a CCD camera. Use it with any scope to take photos of galaxies, nebulas, and star clusters – plus the Moon and planets.

The easy-to-use Meade Deep Sky Imager includes the Autostar Software Suite of planetarium and imaging control software and the USB cables needed to connect the imager to your laptop computer or PC. Best of all, the entire package is all yours for only $299!

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If you find a lower nationally advertised price on any in-stock product we sell, either in this magazine or on a telescope or camera store's website (chain stores excluded), let us know when you order. We'll meet or beat any delivered price.

Celestron 11" scopes start at only $1699.

The 11" **Celestron Advanced Series** Schmidt-Cassegrains make big aperture astronomy affordable. With almost twice the light-gathering of an 8" scope, an 11" shows you more deep space wonders than an 8" – *for about the same price.*

The 11" Advanced Series telescopes available from our stock include:

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C11S-GT go-to equatorial ..... **1999**[00]
C11S-GT go-to with XLT coatings ..... **2279**[00]

The C11S and C11S (XLT) have a German equatorial mount, adjustable height tripod with 2" steel legs, slow motion controls, setting circles, 40mm Plössl eyepiece, and 9 x 50mm finder. Starbright multicoatings are standard on the C11S. XLT multicoatings on the C11S (XLT) give you 16% more light. An optional dual-axis drive is available.

The C11S-GT and GT (XLT) go-to models add dual motor drives and a NexStar computer to automatically find over 45,000 stars and objects for you.

At only 29 lbs for the heaviest piece, they are easy to transport and set up. And, best of all, they are very affordable. A big scope no longer costs a fortune, thanks to Celestron.

11" Celestron C11S
$1699

Premium design Meade Ritchey-Chrétiens.

The **Meade** 10" through 16" modified Ritchey-Chrétien telescopes put virtually the same premium optical design used in the Hubble Space Telescope into affordable and portable telescopes for amateur astronomers. With a wide coma-free field for astrophotography, Ritchey-Chrétiens are the telescope of choice in many professional observatories, including the twin 10-meter Keck telescopes in Hawaii.

The big and fast f/8 Meade Ritchey-Chrétiens are available in four sizes:

The 10" **RCX400 10"** ..... **$4999**[00]
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Each adds a full aperture correcting lens to the R-C design that reduces residual astigmatism so stars are point-8 ke across the entire field. GPS and Level North Technology make aligning on the sky *automatic*. You start observing in minutes. UHTC optics for a 15% increase in light transmission, High Precision Pointing, Permanent Periodic Error Correction, a 2" UHTC star diagonal, a 2" 24mm Ultra Wide eyepiece – the list of standard features just goes on and on.

$6599
Meade 12" f/8 RCX400 Ritchey-Chrétien

Celestron's NexImage captures the solar system in color for only $99.

There's a true CCD at the heart of the **Celestron NexImage** Solar System Imager. It's a Sony HAD full color 640 x 480 CCD with 5.4 micron pixels. It takes high power lunar/planetary images with any brand or size telescope and sends them to your computer to view live or print out later. At only $99, it makes serious solar system imaging affordable for everyone.

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LOOKING INTO MARS. The Mars Express spacecraft will deploy the antennae for MARSIS, its ground-penetrating radar, in the first week of May. The instrument can probe several miles deep, seeking water or ice.

NASA/JPL/MSSS/IMAGE R23–00624

Polar cap's dune collar

ROPES OF SAND. Fields of dark sand dunes surround most of the martian north polar cap. Here, winds from the northwest (upper left) are driving the crescent-shape dunes, called barchans, into sinuous lines. This Mars Global Surveyor image, sunlit from the lower left, is about 1.9 miles (3 km) across.

NASA

FLASH BURNS. A theory suggests gamma-ray bursts set off lightning in the early solar nebula, melting rock particles.

Chondrites and GRBs

Gamma-ray bursts (GRBs) may have spawned lightning storms as large as the solar system, fusing primordial dust grains into chondrules — the BB-size spheres that abound in stony meteorites.

A team led by Brian McBreen (University College, Dublin) proposed this model after calculating that gamma-ray bursts alone were too rare to account for all the chondrites, some of which have melted several times.

Scientists envision lightning storms with bolts crackling a tenth of the Earth-Sun distance and with a trillion times the energy of terrestrial flashes. — ROBERT ADLER

NASA/JPL/MSSS/IMAGE R22–01171

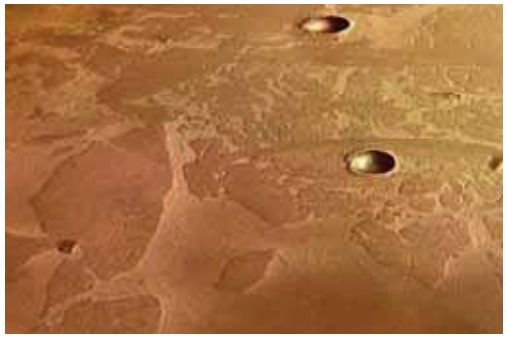
EXHUMATION. A circular butte, once an impact crater, stands above a wind-fluted landscape on Mars. Filled with sediments, the ancient crater proved tougher to erode than its surroundings. Sunlit from the upper left, this image from Mars Global Surveyor spans 1.9 miles (3 km).

Frozen sea underground on Mars?

A frozen sea may lie on Mars under Elysium Planitia, says a team of geologists who studied Mars Express images showing pack-ice-like features.

The area forms a basin about 500 miles (800 km) across and 150 feet (45 m) deep — like the North Sea.

According to team leader John Murray (Open University, U.K.), volcanic ash landed on the ice covering the sea, mixing with it as the ice slowly evaporated.



ESA/DLR/FU BERLIN, G. NEUKUM

PACK ICE? Irregular slabs resembling arctic pack ice hint a frozen sea lies buried near Athabasca Vallis on Mars. The scene here is about 25 miles (40 km) wide.

"Breakup came as the sea drained to the east," he says, noting some floes drape across crater rims.

Crater counts date the floes as 5 million years old; the areas between are a million years younger. — R. B.

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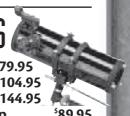

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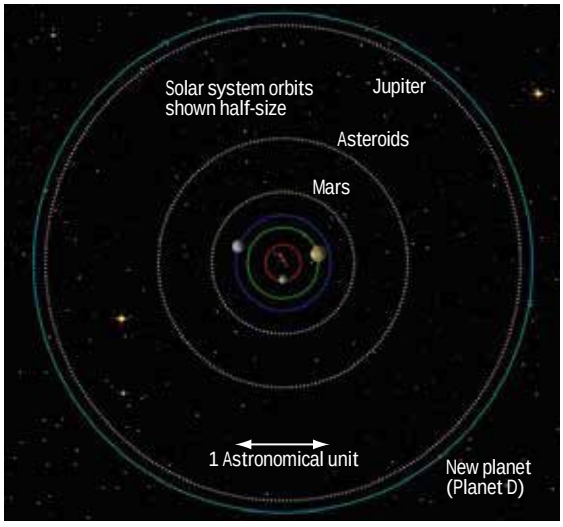
STELLAR HEAVYWEIGHTS. How massive can a star get? Answer: 120 to 200 times the Sun's mass, according to a statistical study by two astronomers who examined a dozen associations of massive type O and B stars.

NASA/ESA/HUBBLE HERITAGE TEAM

V838 Mon's evolving dust shroud

A BLAST WAVE GROWS. Light echoes from an outburst by the irregular variable star V838 Monocerotis continue to expand into the clouds of dust shed by the star in prior eruptions. These two Hubble Space Telescope images show almost 9 months' change.



PSU/A. WOLSZCZAN

HALF-SCALE SOLAR SYSTEM. A fourth planet has been discovered 1,500 light-years away orbiting the pulsar B1257+12 in Virgo. Curiously, the spacing of the planets' orbits resembles a half-size model of our inner solar system.

Smallest exoplanet found — and it orbits a pulsar

The pulsar B1257+12 was the first object outside the solar system discovered to have a planet orbiting it, in 1992. The discoverer, Alex Wolszczan (Pennsylvania State University), eventually identified three terrestrial-size planets around the pulsar.

Now, along with colleague Maciej Konacki (Caltech), he says there's a fourth planet in the system, orbiting farthest from the pulsar and having a mass only 4 percent that of our Moon. They discovered the new planet by tracking periodic changes in the star's pulses, the technique that uncovered the previous planets.

"Our observations also rule out the idea of any more planets as big as these," adds Wolszczan.

This pulsar-planet system had already surprised astronomers because the three previously known planets have orbits spaced almost exactly proportional to the spacing of Mercury, Venus, and Earth. The new body, dubbed Planet D, orbits 6 times farther than the third planet. In part, the system resembles a half-size model of the Sun's planetary system.

Pulsar planets are not primordial, say astronomers. That is, they did not form when the star that became a pulsar did. Instead, says Wolszczan, these planets hint the system probably had a second star in orbit originally. At some point, the companion was torn apart by the star that became a pulsar. The planets then formed out of the debris of the companion star. —R. B.

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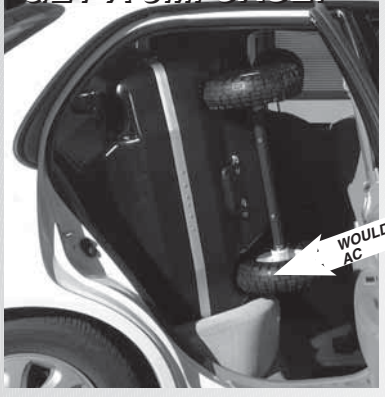

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Stellar archaeology

Milky Way star clusters come in two forms — open and globular. Now, some astronomers suspect they are related. /// BY FRANCIS REDDY

One of astronomy's fundamental conceits is that Earth orbits an average star, which coasts through a nondescript portion of our Milky Way, a typical spiral galaxy.

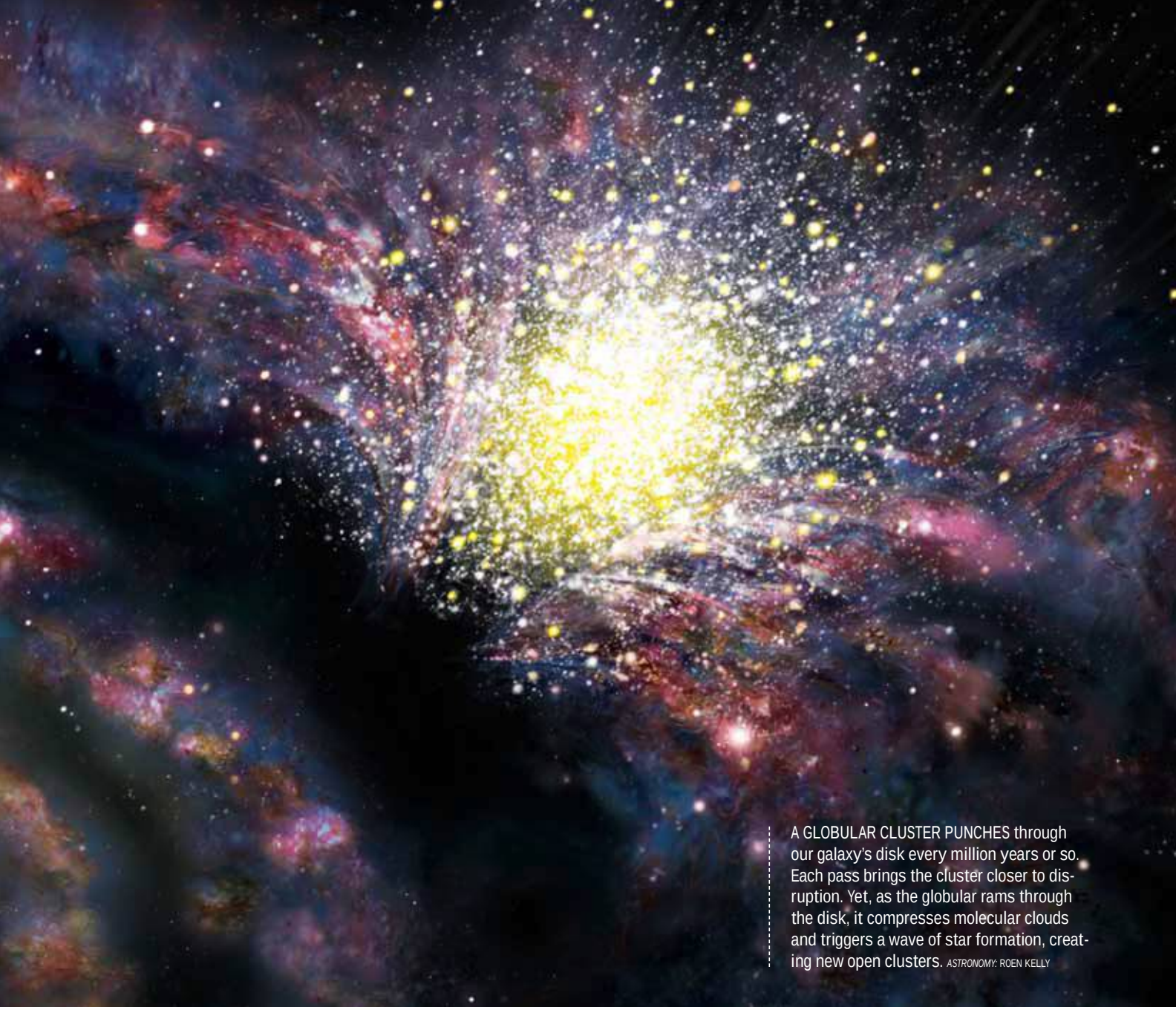
It's a notion that harks back to Copernicus — he did, after all, nudge Earth from the center of the universe — but it also dovetails with the natural human tendency to regard those things most familiar to us as normal.

Our location in the Milky Way Galaxy gives astronomers a great opportunity to see how stars live and die. One of the best ways to see this comes from star clusters, groups of newborn and aged stars that hang together and provide important clues about the past.

What has become clear during the past decade is that the way astronomers have traditionally characterized star clusters — classing them as either open or globular, the two forms seen in our home galaxy — no longer holds up. Colliding galaxies, or those undergoing an intense burst of star formation, seem filled with objects that don't easily fit into either category. In the past few years, astronomers have found hard-to-classify clusters even in normal spirals, galaxies otherwise like our own.

Star clusters have been objects of intense study for more than a century. They are the glittering gems of the night sky, aggregations of a few hundred to about a million stars, usually forming a single gravitationally bound entity.

Most stars probably form within clusters, so the problem of understanding star formation is inextricably linked to understanding how clusters form. Clusters are important because they provide a sample of stars at the same age, with about the same chemical content,



A GLOBULAR CLUSTER PUNCHES through our galaxy's disk every million years or so. Each pass brings the cluster closer to disruption. Yet, as the globular rams through the disk, it compresses molecular clouds and triggers a wave of star formation, creating new open clusters. *ASTRONOMY:* ROEN KELLY

and at the same distance from Earth — which makes them useful for testing stellar evolution. Because star clusters can be identified and studied in other galaxies at distances where individual stars can no longer be distinguished, they give astronomers insight into star-formation processes across a broad expanse of space and time.

"We live in the Milky Way, and as a result, we have a certain perspective about what we might call a star cluster," says Rupali Chandar, an astronomer at the Space Telescope Science Institute (STScI) in Baltimore, Maryland. In our parochial view, star clusters come in two flavors — open and globular — that at first glance could not be more different.

The view from within

Open clusters reside in our galaxy's disk, typically contain stars no older than a billion years, and hold a few hundred to perhaps a few thousand solar masses. Their stars exhibit metallicity — the complement of elements heavier than helium — similar to or greater than our Sun's. Open clusters range in size from several to more than 50 light-years across and appear diffuse and irregularly shaped. About 1,000 have been cataloged, with the most famous examples being the familiar Pleiades and Hyades in Taurus. Thousands more likely exist beyond our ability to detect them.

Globular clusters ride orbits highly inclined to the Milky Way's disk and are associated with its more spherical halo and bulge components. Globulars typically contain 100,000 solar masses, all of it packed into a spherical or elliptical volume 100 or so light-years across. With ages around 12 billion years, globular clusters are truly ancient objects, a fact reflected in the low metallicity of their stars. About 150 globulars — including several visible to the unaided eye — orbit the Milky Way.

Star clusters in the Andromeda Galaxy, the nearest spiral, appear to break down in

MANY MASSIVE, YOUNG STARS make the famous Double Cluster in Perseus one of the brightest stellar collections in the Milky Way Galaxy. The two open clusters, known individually as Chi (χ) Persei (NGC 884, at left) and h Persei (NGC 869, right), formed 11 million and 12 million years ago, respectively. Only about 100 light-years separate the pair. Both clusters are visible to the unaided eye despite lying 7,000 light-years away from us.

much the same way. "If we lived in Andromeda, I think probably it would reinforce our view of this dichotomy in cluster properties," Chandar says. But astronomers in a more extreme galactic environment — such as a galaxy undergoing a burst of intense star formation, like M82, or galaxies in the process of merging, like the Antennae — would reach starkly different conclusions.

"The main result [of work over the past decade] is that any time you look at starburst and merging galaxies, you see very rich systems of young, compact clusters," she explains. "The most massive end of these, the brightest end, has all the properties — masses, sizes, current luminosities — we would expect of young globular clusters." If we could look at these massive, young clusters far in the future, when the universe is twice its current age, they'd resemble the globular clusters we see orbiting the Milky Way today. Moreover, these objects aren't unique to disturbed galactic environments. They occur in normal spirals like M83 and NGC 6946, too.

When astronomers re-examine the Milky Way's cluster system with this realization in mind, the once-clear distinction between open and globular clusters becomes blurred. At 10 billion years old, Berkeley 17 is considered the oldest open cluster, but it overlaps the range of globular-cluster ages (8 to 12 billion years). The two cluster types show a slight overlap in metal content as well. And then there are clusters where classification simply has been ambiguous. Søren Larsen of the

OPEN OR GLOBULAR? Discovered in 1964 in the constellation Norma, Lyngå 7 was originally classified as an open cluster. Decades later, astronomers recognized its stellar content was closer to that of a globular cluster.

MESSIER 13, located in the constellation Hercules, is a globular cluster some 23,000 light-years away. M13 holds some half a million stars bound together by their mutual gravitational attraction.

LYNGÅ 7: ATLAS IMAGE MOSAIC BY S. VAN DYK, COURTESY OF 2MASS/UMASS/IPAC; M13: CALTECH/NASA/NSF CANADA-FRANCE-HAWAII TELESCOPE, J.-C. CUILLANDRE, CÖELUM

Francis Reddy *is an associate editor of* Astronomy.

/// BRIGHTEST YOUNG CLUSTERS

When compared to young star clusters in other galaxies, the Milky Way's brightest turn out to be about average. The following lists absolute magnitudes for the brightest young clusters in a range of galaxies.

IC 1613: –6

NGC 1023 and NGC 3384: –6.5; these are Larsen's faint fuzzies.

Milky Way: –7 for NGC 3603, Arches, and Quintuplet; –9 for the Perseus Double Cluster

NGC 3184: –10.5

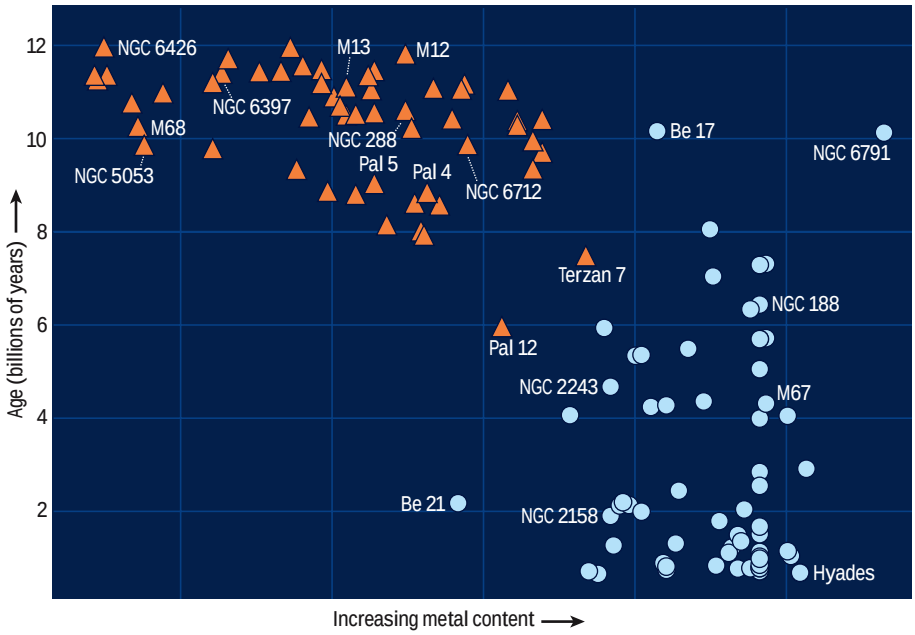
Large Magellanic Cloud (LMC): –11 for R136

M83: –12

M51 and NGC 6946: –13

NGC 4038/NGC 4039 ("Antennae"): –14

N. A. SHARP/NOAO/AURA/NSF



EVEN WITHIN THE MILKY WAY, the dividing line between globular clusters (triangles) and open clusters (circles) is blurred. Most globulars formed between 10 and 12 billion years ago, but there are a few objects only half that age. The proportion of metals — elements heavier than helium — also overlaps for both cluster types.

European Southern Observatory says, "Consider the Milky Way clusters NGC 2158, NGC 6791, NGC 5053, and Terzan 3, all of which look very similar. But the first two are classified as open and the other two as globular."

Looking beyond the Milky Way

The Large Magellanic Cloud (LMC), a satellite of the Milky Way, confuses the issue further. In 1930, Harlow Shapley referred to the LMC's "blue globular clusters," recognizing that these objects couldn't be shoehorned into either cluster category. Both the LMC and spiral galaxy M33 have formed these objects, also known as "blue populous clusters," more or less continuously.

Additional cluster types described in the astronomical literature include super star clusters (in M82) and young, massive clusters (in the Antennae). The most recent entry — faint fuzzies — comes from a 2002 study by Larsen and Jean Brodie of the University of California's Lick Observatory. They discovered these objects on Hubble Space Telescope images of galaxies NGC 1023 and NGC 3384. A follow-up investigation with the Keck I Telescope in Hawaii revealed faint fuzzies to be 8-billion-year-old, metal-rich star clusters up to 5 times larger than typical open or globular clusters. No such objects occur anywhere in the Local Group, the assemblage of galaxies that includes our Milky Way.

"The general idea has always been that these clusters formed from different mechanisms, that there must be something different in how the star formation was actually triggered," explains Chandar. In other words, certain types of clusters may form only in certain types of galaxies — a notion STScI astronomer Bradley Whitmore playfully has called "special creation."

Instead, Whitmore, Chandar, Larsen and others see tantalizing evidence for an underlying property that connects different classes of star clusters. Most studies of young clusters show their stars' luminosities follow a mathematical relationship called a power law. Plotted on a logarithmic scale, the number of ultraluminous stars, and the number of modestly bright stars, trace out a straight line. Open clusters in the Milky Way also seem to display the same demographic feature.

This distribution of luminosities within individual clusters — called the cluster's luminosity function — shows little variation among clusters in the same galaxy. But what's even more surprising is that when astronomers compare luminosity functions for clusters in different galaxies, the results seem to converge on a single, "universal" luminosity function.

"This suggests that merging galaxies have the brightest clusters only because they have the most clusters," says Whitmore. "It appears to be a matter of simple statistics rather than a difference in physical formation mechanisms."

At first glance, the demographics of old globular clusters seem to be at odds with this conclusion. Globular clusters, which once were thought to form in a way uniquely related to the physics of the early universe, appear to be forming today as young, massive clusters. However, globulars follow a bell-curve-shaped distribution. Says Chandar: "This bell-curve shape was interpreted for many years as meaning that globular clusters formed with a preferred mass — the mass at the [curve's] peak — rather than as the result of evolution."

One way out of the difficulty is to imagine that smaller globulars evaporate with time, a process demonstrated in computer simulations for many years. Over time, as the stars in a cluster interact gravitationally, stars of different masses take up residence in different parts of the cluster. Like water settling in oil, massive stars — and those linked gravitationally as binaries — work their way into the cluster's center at the expense of low-mass stars, which move outward into the cluster's fringes. The

/// CLUSTER'S LAST STAND

A globular cluster is not forever. Its steeply inclined orbit repeatedly takes it through the disk or central bulge of its parent galaxy. Galactic tides can strip off a cluster's most loosely bound stars. And each time a globular makes its closest approach to a galaxy, it experiences rapid changes in the galactic gravitational field's strength. This creates a "tidal shock" that stirs up the globular like a quick shake to a snow globe, sending stars to the cluster's fringes.

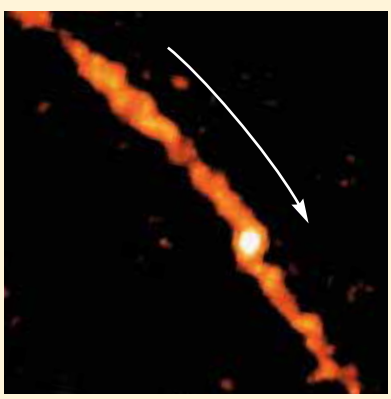
Astronomers lacked direct evidence these processes occurred until 2000, when images taken during commissioning of the Sloan Digital Sky Survey (SDSS) revealed a globular named Palomar (Pal) 5 lies embedded in a starry trail of its own making.

Pal 5 is one of many sparse, faint, low-mass globular clusters orbiting the Milky Way. It lies about 75,000 light-years away, which is about as far from the Sun and our galaxy's disk as Pal 5's orbit will take it.

Follow-up studies showed the cluster's faint debris trail spans at least 10° (20 times the diameter of the Full Moon, or about 13,000 light-years) and that this globular has been drizzling stars into the Milky Way's halo for at least 2 billion years. In fact, astronomers estimate Pal 5's tidal tails now hold 20 percent more stars than the cluster itself.

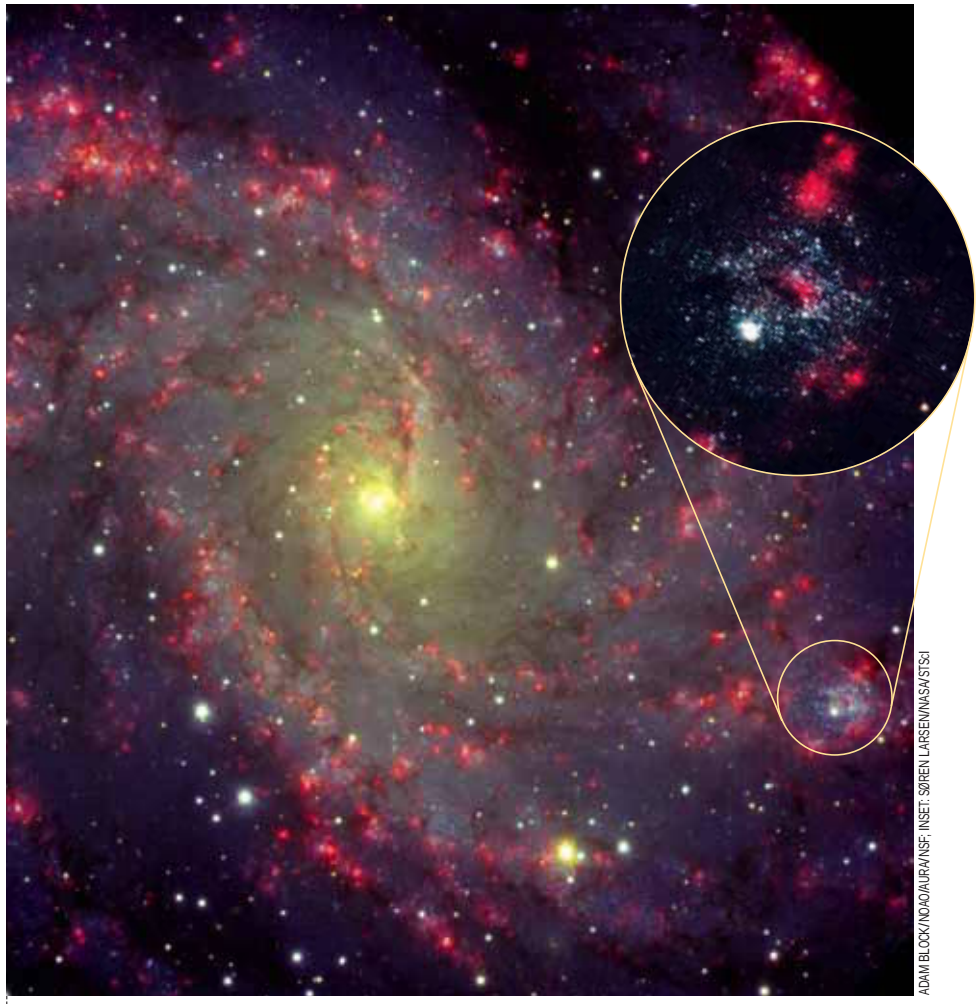
Pal 5's next encounter with the Milky Way's disk, about 100 million years from now, likely will destroy it completely.

— Francis Reddy



MICHAEL ODENKIRCHEN ET AL./SDSS

ESCAPED STARS TRACE the orbit of Pal 5 (white knot). One trail of castaway stars leads the cluster, another follows. The arrow indicates Pal 5's orbital motion.



ADAM BLOCK/NOAO/AURA/NSF; INSET: SØREN LARSEN/NASA/STScI

SUPERNOVAE POP OFF frequently in NGC 6946, a bright spiral galaxy in Cepheus. Eight stellar explosions have been recorded there since 1917, a clear sign of intense star formation. *Inset:* One of the bright knots in the galaxy's arms resolves into a brilliant cluster with a mass of roughly a million Suns. The object, which many refer to as a young globular cluster, spans about 420 light-years and has a compact core just 8.5 light-years across.

galaxy's gravitational field strips away those stars that stray too far.

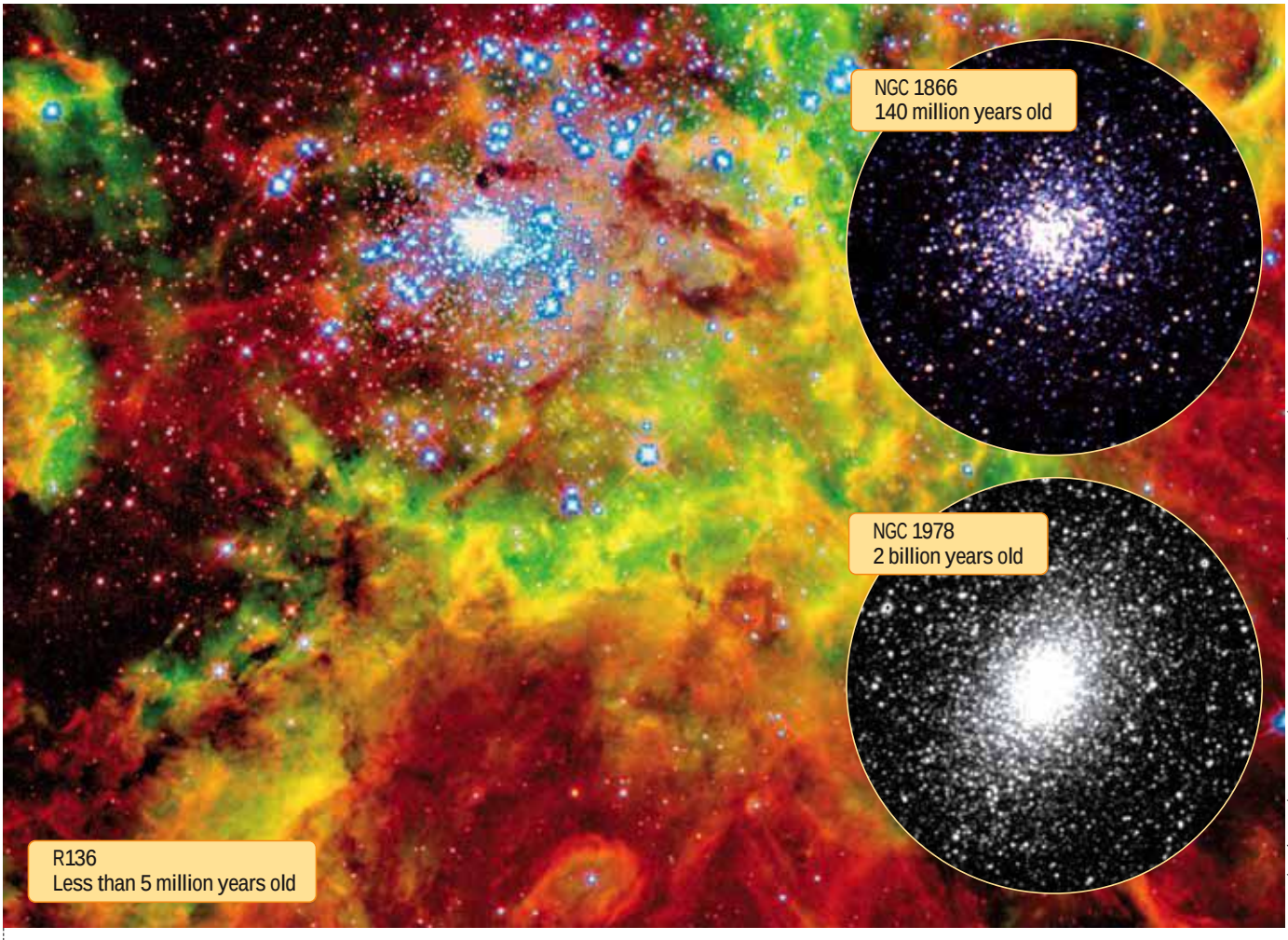
Sooner or later, globulars must pass close to their parent galaxy's bulge or plunge through its disk. During these encounters, globulars experience rapidly changing galactic tides. Each such "tidal shock" speeds cluster stars in their orbits and sends them careening into the globular's fringes. Once there, these loosely bound stars may be stripped from the cluster at a later time.

Evaporating clusters

Until recently, there was no observational evidence that globulars actually dissolve. In 2000, a team led by Michael Odenkirchen of the Max-Planck-Institut für Astronomie in Heidelberg, Germany, found twin tails of stellar debris arcing away from the faint globular cluster Palomar (Pal) 5 (see "Cluster's last stand" at left). Subsequent studies found tidal tails issuing from 20 other globulars, including NGC 288, and Pal 12 and 13. Globular clusters *do* evaporate, and astronomers observe only the most massive remnants of the Milky Way's original globular population today.

Further evidence in support of a unified view of clusters arrived in 2003. A team led by Richard de Grijs of the University of Cambridge, England, examined a billion-year-old "fossil starburst" at the center of M82, the nearest and best-studied starburst galaxy. Tidal interactions with neighbors M81 or NGC 3077 probably triggered M82's fierce pulses of star formation.

The astronomers looked at a region where they had previously identified more than 100 gravitationally bound clusters. If the unified view is correct, then many



R136: JESÚS MÁIZ-APELLÁNIZ AND NOLAN WALBORN (STScI) AND RODOLFO BARBÁ (OBSERVATORIO ASTRONÓMICO DE LA PLATA); NGC 1866 AND NGC 1978: SØREN LARSEN (ESO)

A STAR FACTORY CLOSE TO HOME, the Large Magellanic Cloud (LMC), a satellite of our own galaxy that lies some 170,000 light-years away, has been making young, massive star clusters more or less continuously. R136, the brilliant young cluster in the Tarantula Nebula, has a mass of 30,000 Suns. NGC 1866 and NGC 1978, two of the LMC's "blue populous clusters," have roughly similar masses — about 100,000 Suns — but vastly different ages.

low-mass clusters that formed in this episode of star formation have already evaporated. If de Grijs and his colleagues could see sufficiently faint clusters, they'd be able to determine if those in M82 follow a bell-curve distribution like globular clusters.

In fact, de Grijs and his team did just that. They produced conclusive evidence that young clusters show characteristic luminosities and distributions nearly identical to globulars orbiting M31, M87, old elliptical galaxies, and our own Milky Way. Young globular clusters are, indeed, forming today, and the distinctions we make regarding the Milky Way's clusters are artificial at best. Some astronomers, like Whitmore, suggest it's time to create an objective classification system for star clusters, one that provides more meaningful terminology for clusters near and far, young and old.

Still, there remain many caveats with the "continuum view" of star clusters. "Clearly, things become more complicated once you start looking at the details," says Larsen. As early as the 1950s, astronomers realized the Milky Way's globular clusters contain different populations distinguished by metal content, location, and orbital motion.

"The origin of the different subpopulations is currently a matter of much debate, and we are still very far from having a clear picture," explains Larsen. "Generally, the halo globular clusters appear to fall into two groups, based on ages and other properties, and the younger ones may have been accreted."

The Sagittarius dwarf-spheroidal galaxy, which is now passing through the Milky Way's disk, may have contributed a handful of globulars, including Terzan 7 and 8, Arp 2, Pal 12, and M54 — an object some astronomers point to as the disrupted galaxy's nucleus. Omega Centauri, the Milky Way's most massive globular, likewise may be the stripped nucleus of another dwarf.

In a 2004 study of globular subpopulations, A. D. Mackey and G. F. Gilmore of Cambridge University's Institute of Astronomy estimated that our galaxy has experienced at least seven merger events. They argue as much as half the stellar mass in the Milky Way's halo originated in cluster-bearing dwarf galaxies swallowed by our own. If so, then young globulars are the remnants of our most recent acquisitions.

For every cluster that survives to an age of 10 billion years, a thousand were created and have been destroyed, their stars dispersed throughout the galaxy. To put an astronomical twist on Mark Twain's famous quip about thunder and lightning, galaxies are impressive, but it's star clusters that do the work. A

Can a globular make an open cluster? See www.astronomy.com/toc for more.

{ INTERVIEW }

Space Bu

Apollo 11 Moon-walker Buzz Aldrin talks about the future of space flight.

When you sit down with Buzz Aldrin, you feel the presence of a larger-than-life figure. Although he is now 75 with tufts of white hair edging his head, the passion and energy are still very much in the retired astronaut and fighter pilot, as evidenced by the intensity of his eyes, articulate ideas, and deep thoughts. The second man to walk on the Moon, some 35 years after the fact, remains a highly impressive human being.

For three of *Astronomy*'s editors, Robert Burnham, Frank Reddy, and me, and Mark Paternostro of Chicago's Adler Planetarium, the moment came together in a strange place. Always a friend and supporter of the magazine — and a member of our editorial advisory board — Aldrin spent a day at the iHobby Expo, the international toy and hobby fair, in Chicago in October 2004. We had a short time to talk with him, squeezed into his busy promotional schedule. By the time Aldrin sat down with us, relieved to be talking about space exploration and weary from signing autographs, he seemed in his element. We talked for more than 90 minutes and produced more than 7,000 words, mostly on where he sees space programs going.

Apollo 11, the Moon mission he completed with Neil Armstrong and Michael Collins — an event that transfixed the world — is only one milestone in the Aldrin tapestry. A native of New Jersey, he is the son of an aviation pioneer who studied rocketry under Robert Goddard. Aldrin was graduated third in the West Point class of 1951 and flew 66 F-86 combat missions in the Korean War, shooting down two MiG 15s. He was selected as an astronaut in 1963.

DAVE EICHER

"IF WE CONTINUE TO QUESTION what we decide to do, then we have a problem."

Altogether, Aldrin logged 290 hours in space. He flew on Gemini 12 with James Lovell before walking on the Moon during the historic Apollo 11 mission. Since resigning from NASA in 1971, he has remained at the forefront of promoting America's leading role in space exploration.

Aldrin has created a plan for a spacecraft he calls "The Cycler," which would shuttle between Earth and Mars. He received a patent for a space-station design. His rocket-design company, Starcraft Boosters, and the nonprofit ShareSpace Foundation, devoted to space tourism, take much of his time and energy these days.

Aldrin has written five books and numerous articles on his adventures. He actively speaks, travels, and analyzes space exploration and technology. Our opportunity to talk with him produced an array of thoughts about the past, present, and future of space flight — the highlights of which follow. — *Dave Eicher*

Astronomy: Where do you think space flight is going, and how do you think the private space sector will develop?

Aldrin: Well, we're just beginning to see private space companies trying to launch satellites with small and medium payloads. The big companies were the ones that were involved in government military launches.

Private companies haven't had a great amount of success. I'm thinking of the number of rocket companies that have tried to get underway. Orbital Sciences succeeded fairly well. Kistler Aerospace introduced reusable two-stage rockets, but they're bankrupt now and trying to figure whether they can come out.

Now, in terms of adventure travel initiated by the X Prize, that's taking a little bit longer to develop than we thought. There are lots of ideas, but really only one [Scaled Composites] that so far has come anywhere close to trying to develop what was envisioned by the prize: something that might be converted into a commercial activity. And it looks like after demonstrating the capability with SpaceShipOne, it's not commercially attractive. There aren't enough people on board, so they're going to defer trying to get it qualified for commercial operations and not fly it again, but instead go for a more viable number of passengers.

Astronomy: What do you think about the Moon-to-Mars initiative?

Aldrin: We really have to complete the space station first, if at all possible. That means we have to return to flight and then, as soon as possible, retire the shuttle by 2010 perhaps and not keep it going until 2020 or 2025. Those were all good decisions.

Now, how can we afford to do that in this political environment, with an economy that doesn't look good and a war going on? I evaluate what was offered by the president as being very good. Where do we want to go? Not just to Mars. If we ever skipped the Moon and said we're going to go straight to Mars, it would get bogged down in the

BUZZ ALDRIN WALKS on the Moon July 20, 1969, becoming the second human to set foot on another world.

NASA

DAVE EICHER

AFTER WE RETURN TO THE MOON, "I think we should follow up on asteroid detection and characterization by having robotic visits followed by a human visit to an Earth-crossing asteroid."

process of design without much happening. We'd end up going once or twice and then it's canceled.

But if you build up the capability, and you don't get stuck in just going to the Moon … it's a question of future management. I think we need to spell out what we're doing not in NASA decadal intervals, but in political 4-year intervals that start January 20 of the post-election year, when the president takes office. That's when he institutes his 4-year plan. We can't just have successive new programs every 4 years, we need to look ahead eight or nine 4-year programs — chart out in that grid what it is we think we can do. The closer it is to the present time, the more precise it is. It gets more nebulous out in the future. By the eighth plan, in 2033, we ought to have reached Mars. I think it's a good plan that's been set out.

One problem is that we have left a big hole by not having a lifeboat at the International Space Station. And that's unfortunate because I suggested the X-38, which was a lifeboat only, wasn't versatile enough. For us to build that when it wouldn't provide alternate transportation probably would have been a mistake. But, when NASA canceled the X-38 without a follow-on and some possible competition, it left us in a pickle. Now, exploration is going to defer that even further.

Astronomy: How much international cooperation do you think we should seek in doing these projects?

Aldrin: I want to visit China to inquire about their Shenzhou rocket. I think I could try to build consensus around our country encouraging the use of Shenzhou as a possible lifeboat. If a lifeboat is built in China, it would compete with Russia's Soyuz, which will then drive the Russians to lower their cost and not put so much of it on their international partners.

The Russians will be encouraged to put their money into Kliper [for "clipper ship"], which is a six-person vehicle, and a much better design. And then, if that design also can be useful to international exploration efforts, we can have a commonality of components in some parts of the design for a crew-carrying, passenger-carrying spacecraft. We'd have an assured human access to space, which is something that's needed.

We can't really begin exploration when we have the potential for a single failure that can ground our ability to get people up and down when we've got people at the Moon or somewhere else. We have to have something else in our overall plan. And I think that can come from the gap that exists by bringing China in and moving Russia to do something better.

Astronomy: What do you think of NASA's decision on servicing Hubble?

Aldrin: The whole idea of canceling a human shuttle mission to Hubble was clearly poor public relations, and poor timing in the announcement. I think it should have been anticipated. The groundwork should have been laid where the top priorities were the criticality of flight safety and the crucial question of how many missions we can fly before we approach the shuttle's retirement, which we'd like to see in 2010. I think it's going to be very difficult to fly all the station-assembly missions with the shuttle and finish by 2010. The difficulty of adding one or two more missions for servicing Hubble was behind the desire not to send a crew there as much as anything else.

Well, what else can we do? We can develop the robotic ability to accomplish the mission. We need to develop that capability anyway, to do things like attach a reentry propulsion module to Hubble.

The situation wasn't handled too well. I know a lot of people say maybe it's simpler to send a shuttle there and fix it. I guess we can always do that. I would rather let the president set a course and then support it. Let NASA decide it's not going to service Hubble. And then, if that won't work, we do something else. So I tended to support the decisions that were made rather than disturbing the whole setup by questioning what we're doing. If we continue to always question what we decide to do, then we have a problem.

I'm a military guy. We've got to have a chain of command. We've got to make

NASA

> … we should commit to a permanent settlement on Mars before we start making big investments.

some decisions and then stick by them. If we don't like them, elect somebody else and then carry out a different set of plans.

There's a lot of good work Hubble can still do. It's a big investment we've made. But it's already exceeded its design life, and we should move on to other things.

We could keep flying the shuttle until there's only one left. There's a tendency in government never to terminate things when they should be terminated. You move on to something else. Sure, you can continue to put money into something and get a little bit more out of it. Then, if somebody who's in a position to make those judgments and has been given that responsibility decides to do that, I'm in favor of letting that decision stand. Instead of saying: "Hey, wait a minute, that's disturbing my pet idea." Now we've wasted a lot of time arguing about things. That just goes with discipline, organization, and chain of command.

Astronomy: Where should we go after we return to the Moon?

Aldrin: I think we should follow up on asteroid detection and characterization by having robotic visits followed by a human visit to an Earth-crossing asteroid. This is what we would want to do to bring resources back. The first purpose, though, is to demonstrate, maybe robotically, that we can somehow nudge an asteroid to keep another one that is going to impact Earth from actually impacting. It's planetary defense.

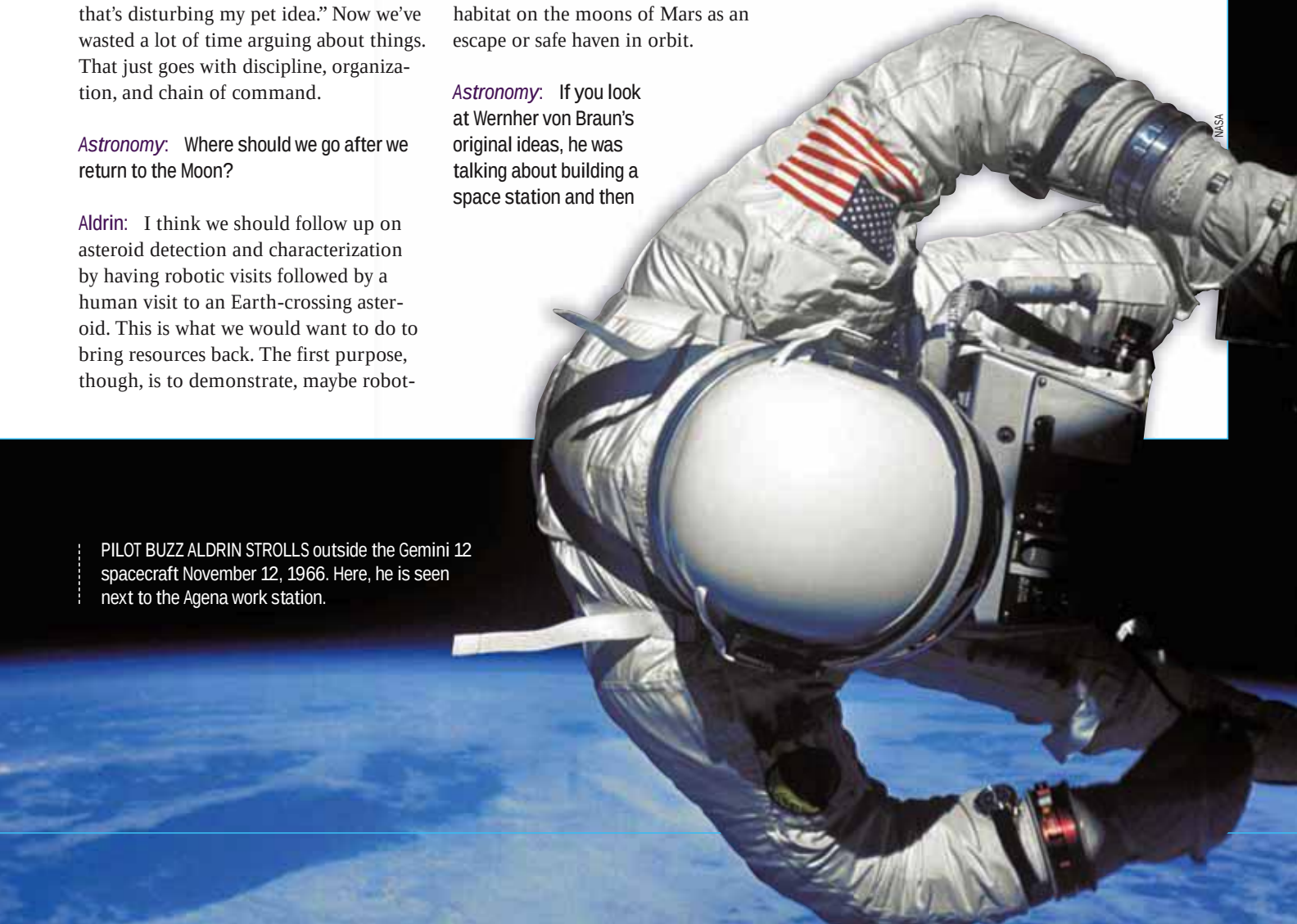
I think that after human landings and resource acquisition on the Moon, we should tend to withdraw people from there and automate lunar missions. The next step is a human visit to an asteroid once or twice. That would serve as a precursor to a mission to the moons of Mars, for at least one Mars launch window and maybe two. Primarily, we would keep crews at the moons of Mars, but they could make forays to the surface and back up again during a year-and-a-half stay, if we feel qualified to do that. But then, we should follow that with missions to Mars' surface, now that you have a habitat on the moons of Mars as an escape or safe haven in orbit.

Astronomy: If you look at Wernher von Braun's original ideas, he was talking about building a space station and then assembling a Moon-ship in orbit. And there would be this space plane that would bring you back to Earth.

Aldrin: The problem with that is you need a lot of propellant when it comes back, if you don't use air braking. I don't think we're quite ready for coming back and grazing the atmosphere, slowing down, and then making the orbit circular. I think we'll go through some of those ideas. What choices we make, perhaps, could be governed by which leads us best to a Mars capability. I'm still an advocate of the efficiencies that are enabled by the use of semi-cyclers or cycler spaceships.

Astronomy: Could you explain those?

Aldrin: Well, in 1985 and '86, I pioneered the idea of Mars cyclers. Basically, you place a spacecraft in an orbit that goes



PILOT BUZZ ALDRIN STROLLS outside the Gemini 12 spacecraft November 12, 1966. Here, he is seen next to the Agena work station.

NASA

PAUSING FOR A MOMENT inside the cramped Apollo 11 lunar module, Eagle, pilot Buzz Aldrin anxiously waits to make the first descent to the Moon's surface.

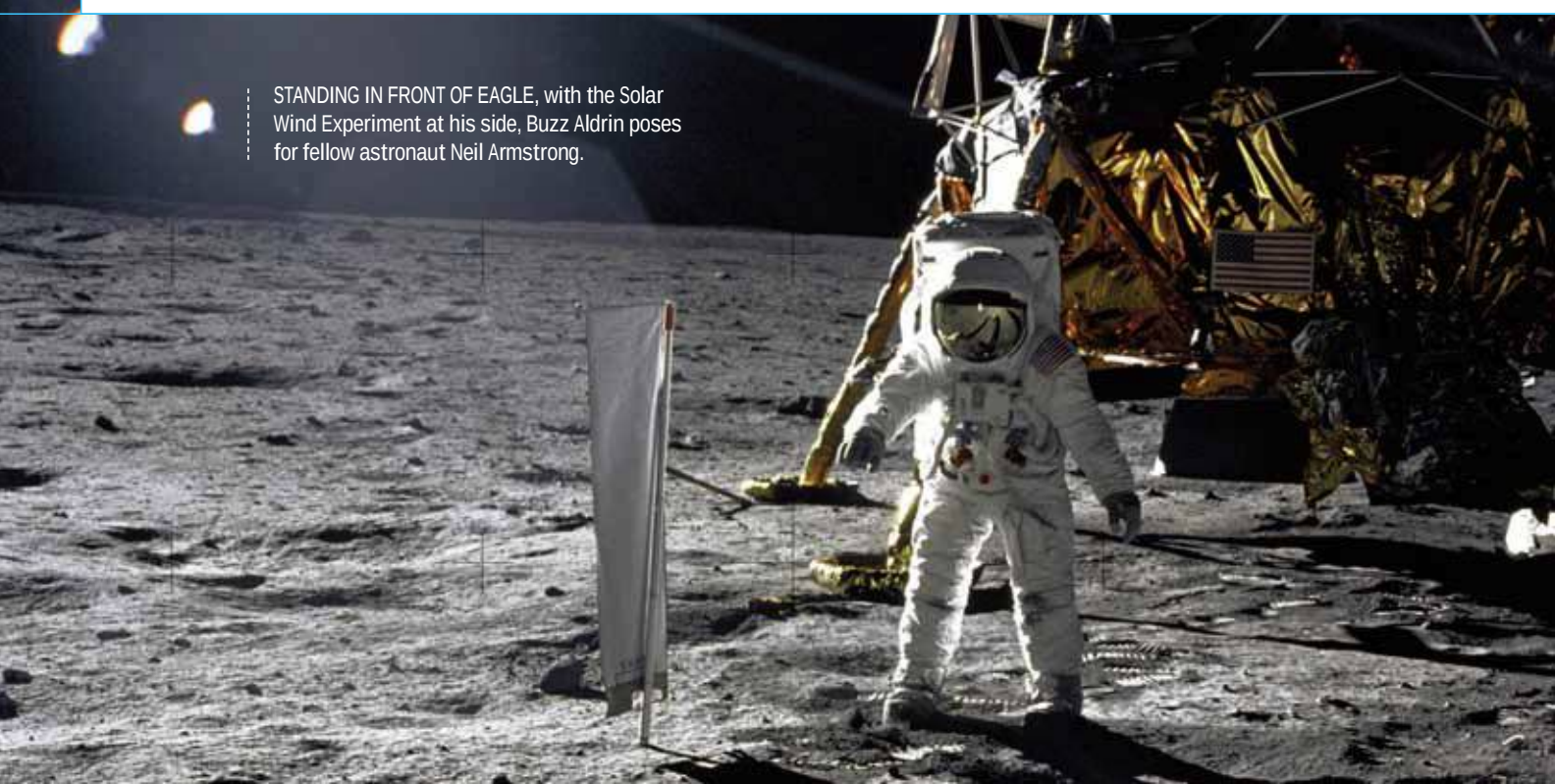
around the Sun, like Earth and Mars, but it ranges from just inside Earth's orbit at closest approach to somewhat outside Mars' orbit at its greatest distance. So, the spacecraft connects the two planets by swinging by each. You get a gravity assist from each swing-by that fine-tunes the trajectory. Then, you have smaller "taxi" spacecraft that deliver crew and cargo from orbit around either planet to the cycling spaceship.

Successive pathways from Earth to Mars change the launch opportunity. By the time the Sun, Earth, and Mars line up, at opposition, you should have left Earth and be about halfway to Mars or you should have left Mars and be halfway back to Earth. Now, that opportunity reoccurs about every 26 months, so the cycling spacecraft's orbital ellipse has to be bent. And the only way to do that is swinging by Earth and getting most of the bending from Earth.

There are ways of easing into this with two cycler spaceships that give you paths from Earth to Mars and Mars to Earth. One cycler is always taking you there; the other is always bringing you back. A disadvantage is that because the spaceship goes quite a bit outside Mars' orbit, the encounter velocity at Mars is fairly high. You intercept the return cycler at a high velocity; we'd like to have it lower. For early missions, this means a very critical intercept is required to get home.

You usually want a backup to that. Well, whatever the alternative is may be a better choice than the primary. That's why you get into the possibility of semi-cyclers, where you have something in orbit at Mars that leaves there, swings by Earth but doesn't stop here, and then goes back to Mars and waits there. That's the semi-cycler. And there are different combinations where you can decrease the velocities. That just hasn't been as thoroughly examined. It will take ingenuity, creativity, and computer time — it doesn't cost a lot of money.

Building a nuclear rocket, testing it, seeing whether you can shorten the transfer time through propulsion — that's expensive. And, besides that, you've got to convince the public it's an acceptable thing to do. We know we need nuclear power for electricity when we get out to Mars' distance. It would be nice to test it at the Moon, in addition to testing other things at the Moon.



STANDING IN FRONT OF EAGLE, with the Solar Wind Experiment at his side, Buzz Aldrin poses for fellow astronaut Neil Armstrong.

Born:
January 20, 1930, in Montclair, New Jersey

Education:
- Bachelor of Science from the United States Military Academy (1951)
- Ph.D. in astronautics from the Massachusetts Institute of Technology (1963)

Air Force:
- Flew 66 F-86 combat missions in Korean War (1950–53)
- Commander of U.S. Air Force Test Pilot School at Edwards Air Force Base, California (1971–72)
- Retired as colonel in March 1972

NASA:
- Selected to third astronaut group in October 1963
- Logged 289 hours and 53 minutes in space
- Flew with James Lovell on final Gemini mission, Gemini 12, in November 1966; established new record for extravehicular activity, spending 5½ hours outside capsule
- Flew with Neil Armstrong and Michael Collins on Apollo 11 in July 1969; became second person to walk on Moon, spending 2 hours and 14 minutes on the surface

DAVE EICHER

"YOU'LL ALWAYS SEND robotic vehicles first, to see what things are like, to prepare the way, to put beacons down."

Astronomy: What about robotic exploration in the future? How do you see things that will be done robotically in the solar system versus manned missions?

Aldrin: I think you'll always send robotic vehicles first, to see what things are like, to prepare the way, to put beacons down, maybe to use the local resources — whether it's the atmosphere of Mars to produce propellants, or whether it's using some surface material and some process to generate propellants, or just to land propellants there ahead of time. Get the places ready so that when you get there, you have augmented your living capacity and your return capacity. You do that robotically. You also can go farther distances robotically.

I think you can carry that maybe one step further, and you start looking at robotics for something close by like the Moon. For communication, it's only a second and a half away. We know how to deal with that kind of lag time. With feedback and the increased ability of automation, we can control robots on the Moon from Earth pretty well. Why do we need people there? Let's send people there initially to set some things up. But there's 14 days of darkness and 14 days of daylight, temperature extremes, no atmosphere, not much water — it's not too good a place.

We can send things up and then have minimum occupancy or zero occupancy. Then, if we need people there, we can send them if we have a good transportation system. So going back to the Moon, you go back with humans as a precursor because you're learning how to operate humans there, and then you're going to use what you learn to operate people on Mars.

Robotics could work in much the same way at Mars. It's clearly advantageous to send a precursor mission to set up some habitable spaceport facility on Phobos or Deimos, whichever moon turns out to be more convenient, or maybe both of them. You then can use them as safe havens. You also get great coverage to control robots all over the martian surface with human intelligence at less than a 1-second time delay.

Now, Mars is not as easy to get to as the Moon. If things go wrong, they're harder to fix; it takes more effort. I definitely think it justifies a growing permanence. So much so that I think we should commit to a permanent settlement on Mars before we start making big investments. Barring some catastrophe, we should establish a settlement and continue to build it up indefinitely. If we're not willing to commit to that, don't go.

Astronomy: On a different note, can you tell us what the Moon looked like while you were heading there on Apollo 11?

Aldrin: Surprisingly, the Moon looks the same until you get quite close. But by that time, it just so happened, our path was taking us in a direction that brought the Sun into view as well. So, as we're approaching the Moon, pretty soon the Moon is big and it eclipses the Sun.

As soon as we looked out and saw this happen — it was really amazing because the Sun was behind the Moon, and the Moon was big and the Sun was small. But there was this glow. There's no atmosphere on the Moon, so it probably was the solar corona we were seeing. What it looked like was a three-dimensional, suspended Moon with this beautiful glow surrounding it. It was like nothing we'd ever seen before. We tried to take some pictures, but they didn't turn out.

Astronomy: And that was on the way?

Aldrin: Well, we were getting pretty close. And pretty soon, we had to knock that off and get pointed in the right direction, because we had to get ready for a maneuver to stay in the Moon's orbit.

That maneuver, of course, worked flawlessly, as did the rest of the Apollo 11 mission. On July 20, 1969, Aldrin watched from a few feet away as Neil Armstrong took a small step onto the Moon's surface. Later, Aldrin voiced the crew's sentiment: "We feel this stands as a symbol of the insatiable curiosity of all mankind to explore the unknown." It's clear, three-and-a-half decades later, Aldrin remains dedicated to that vision. A

To read the entire interview with Buzz Aldrin, visit www.astronomy.com/toc

NASA

Vagabond MOONS

MOON-SIZE FRAGMENTS FLY as bodies in the Kuiper Belt collide. Some pieces will drift inward to become planetary satellites. DAN DURDA

Around each gas-giant planet orbit dozens of small moons born elsewhere. These far-ranging bodies are beginning to give scientists clues to the dark corners of the solar system. /// BY DAN DURDA AND DOUG HAMILTON

Late on a rainy Saturday evening in early October 1997, Brett Gladman carefully searched the star-filled CCD images he had recently helped a team of planetary scientists collect. The star fields surrounded the planet Uranus, and Gladman's elusive quarry were new uranian moons, small objects orbiting far from their giant blue-green parent and bound only weakly to it.

Other astronomers had sought new moons in the environs of the gas-giant planets before, but their searches had been sporadic and new discoveries were few. This time, however, Gladman spotted almost immediately two faint dots moving relative to the background stars at nearly the same rate as Uranus. Subsequent observations confirmed the objects, now named Sycorax and Caliban, were indeed new moons of Uranus.

His discoveries were the first irregular satellites found using a ground-based telescope in nearly a quarter-century. (Irregular moons are those having large, highly eccentric, and often highly inclined, orbits.)

The discoveries came from an astronomical fishing expedition. A team of astronomers including Gladman, Phil Nicholson, and Joe Burns, all then at Cornell University, were observing with the 200-inch (5-meter) telescope on Palomar Mountain in California. They were hunting objects in the Kuiper Belt, a band of small, icy bodies extending outward from Neptune's orbit, 30 times farther from the Sun than Earth.

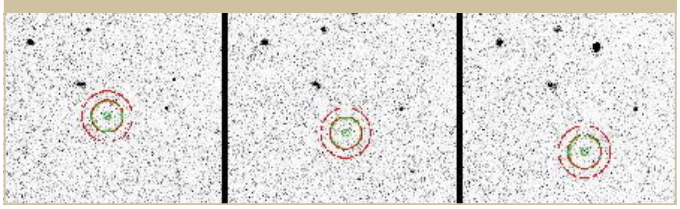
The 200-inch Hale telescope, completed in 1948, was once the world's largest, but numerous 8- and 10-meter telescopes have long since eclipsed it. The venerable instrument, however, still had some surprises in store.

The first hour of the night was unusable for the astronomers' Kuiper Belt program because the star-crowded Milky Way was passing overhead. So the team focused its attention, and the telescope, on two handy targets: Uranus and Neptune. Nicholson reasoned that even though they could search only a small region around each planet, Palomar's modern CCD camera would capture objects 3 to 4 magnitudes fainter than the previous best attempts.

Those were the images in which Gladman spotted Caliban and Sycorax. His initial excitement, however, was tempered with a fair amount of skepticism when he told his collaborators about the result — not all

BRETT GLADMAN, UNIVERSITY OF BRITISH COLUMBIA

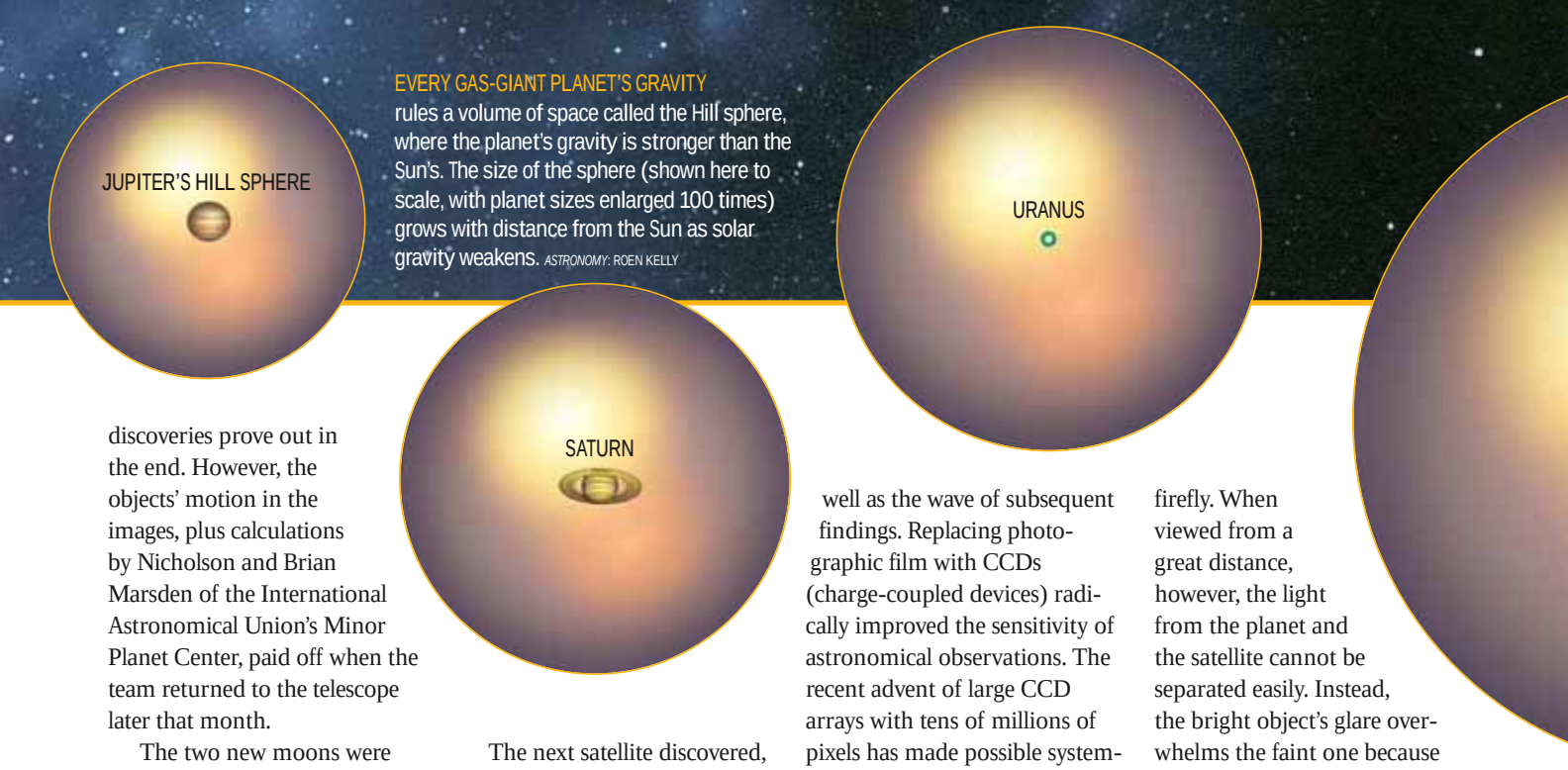
MOON-FINDING, PART 1. Searching for faint moons around bright planets resembles hunting fireflies near a bright lamp. In this mosaic of 72 seach frames (above), Jupiter lies outside the field of view at bottom. Somewhere within these images lurks jovian moon S/2003 J21, circled in the three discovery frames below.



BRETT GLADMAN, UNIVERSITY OF BRITISH COLUMBIA

BRETT GLADMAN, UNIVERSITY OF BRITISH COLUMBIA

MOON-FINDING, PART 2. Discovering moons means sifting through dozens of long-exposure images looking for tiny specks of light moving in just the right way. Here, moon-finder Brett Gladman (left) confers with codiscoverer Lynne Allen.



EVERY GAS-GIANT PLANET'S GRAVITY rules a volume of space called the Hill sphere, where the planet's gravity is stronger than the Sun's. The size of the sphere (shown here to scale, with planet sizes enlarged 100 times) grows with distance from the Sun as solar gravity weakens. *ASTRONOMY:* ROEN KELLY

discoveries prove out in the end. However, the objects' motion in the images, plus calculations by Nicholson and Brian Marsden of the International Astronomical Union's Minor Planet Center, paid off when the team returned to the telescope later that month.

The two new moons were right where expected, slowly swooping around the distant planet. The discovery of two new uranian moons sparked a flurry of satellite hunts and finds over the next 6 years. By now, these have pushed the number of known moons in the solar system to 140.

Mooning the planets

The search for planetary satellites began in 1610, when Galileo Galilei announced the discovery of four large moons orbiting Jupiter: Io, Europa, Ganymede, and Callisto. New discoveries often come from improvements in technology; indeed, the discovery of the four Galilean satellites directly resulted from the invention of the telescope.

The next satellite discovered, Saturn's Titan, was glimpsed first by Christiaan Huygens with an improved telescope of his own design. Ever-increasing telescope sizes, the use of photographic film, and other technological improvements allowed fainter and fainter satellites to be spotted. This culminated in the last ground-based detection of a small irregular moon, Jupiter's Leda, in 1974. In the 1980s and 1990s, spacecraft brought advanced instruments to each of the giant planets in turn and revealed a whole new class of moonlets circling close to their parent planets in and among planetary rings.

New technology drove the discovery of new satellites by Gladman and his colleagues, as well as the wave of subsequent findings. Replacing photographic film with CCDs (charge-coupled devices) radically improved the sensitivity of astronomical observations. The recent advent of large CCD arrays with tens of millions of pixels has made possible systematic mapping of large regions of sky. Ground-based satellite searches today use 10,000 x10,000-pixel CCD arrays capable of covering a quarter-square-degree patch of sky (roughly equivalent to the Full Moon) in a single exposure.

Searches for satellites from the ground neatly dovetail with space-based ones. Where the latter are superior at finding small satellites close to their planets, the former are better suited for efficiently searching regions farther away.

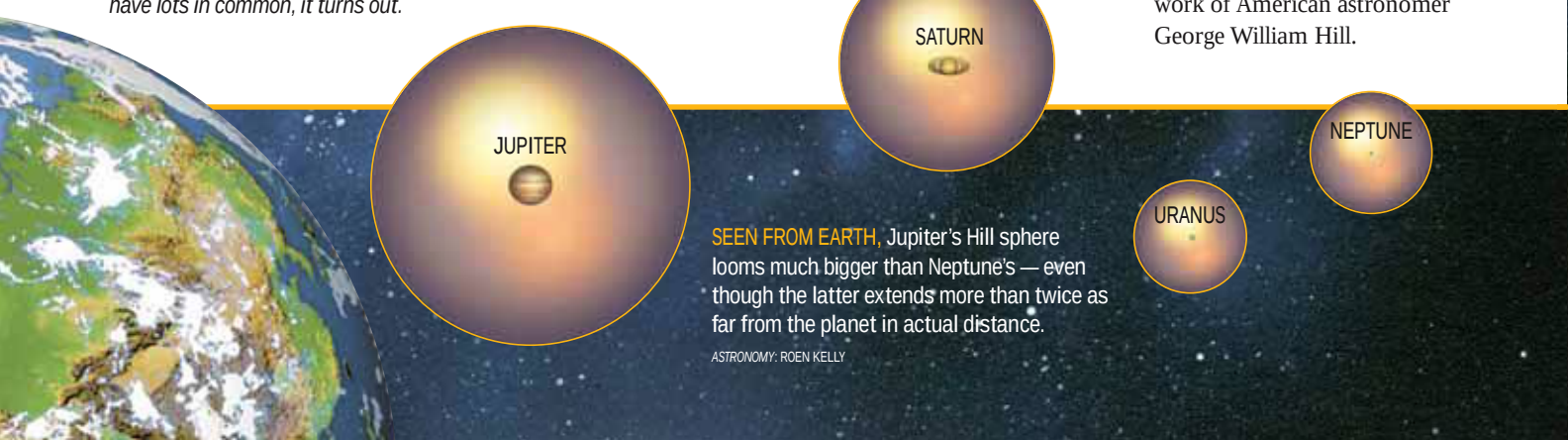
The reasons are geometric. A spacecraft flying close to a planet can focus its cameras on a potential satellite while keeping the much brighter planet out of the field of view, much as a person standing near a bright lamp can turn away to spot a nearby firefly. When viewed from a great distance, however, the light from the planet and the satellite cannot be separated easily. Instead, the bright object's glare overwhelms the faint one because they lie close together.

Despite this, searches for satellites work best from large distances. The person near the lamp must look in all directions to find nearby fireflies, while a more distant observer needs to look only in its general direction to see fireflies circling the lamp.

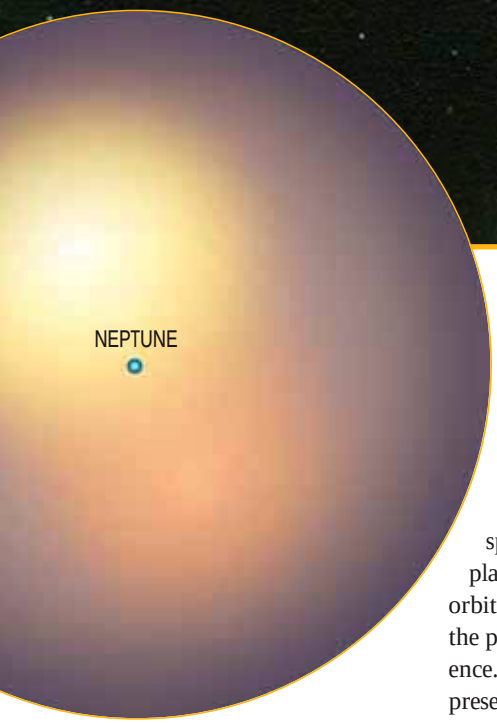
Similarly, telescopes on Earth need to map only a small region of sky around a planet to find new moons rather than the full sky a spacecraft must search. In addition, large-aperture telescopes on Earth are immensely more powerful than the much smaller ones carried by spacecraft. Better instruments and a smaller area of sky to search from Earth more than make up for the advantage in proximity that a spacecraft enjoys.

But how much sky must be searched? The answer lies in celestial mechanics — and the work of American astronomer George William Hill.

Dan Durda *(Southwest Research Institute, Boulder, Colorado) and* Doug Hamilton *(University of Maryland) are planetary scientists specializing in wandering objects such as moons and asteroids — two objects that may have lots in common, it turns out.*



SEEN FROM EARTH, Jupiter's Hill sphere looms much bigger than Neptune's — even though the latter extends more than twice as far from the planet in actual distance. *ASTRONOMY:* ROEN KELLY



NASA/JPL/SSI

OBJECTS THAT HAVE LIVED a knockabout life usually wear their past on their faces, and Phoebe is no exception. The heavy cratering it shows testifies to many billions of years of impacts as Phoebe journeyed from the Kuiper Belt, where scientists think it formed, to its present orbit among Saturn's collection of moons.

Spheres of influence

Hill grew up on a farm in West Nyack, New York. As a student of mathematical astronomy at Rutgers College in the late 1850s, he studied the classic works of celestial mechanics. These included Pierre-Simon Laplace's *Méchanique Céleste*, Joseph Louis Lagrange's *Méchanique Analytique*, and what was perhaps the most influential book in Hill's young career, Charles-Eugènes Delaunay's *Théorie du Mouvement de la Lune*.

While on the staff of the *American Ephemeris and Nautical Almanac*, Hill worked for many years on accurately calculating the Moon's orbit and its long-term stability. There, he developed mathematical techniques for describing orbital motions in a system of three bodies (for example, a moon orbiting a planet that itself circles the Sun). These techniques also outline the region around a planet where a moon can keep a stable orbit.

Today, astronomers call this region the Hill sphere. Far down inside a planet's Hill sphere, a moon's orbital motion is dominated by the planet's gravitational influence. The Sun's gravity is still present, but its pull is minor compared to the more powerful tug of the much closer planet.

Moons deep in a planet's Hill sphere have stable orbits, while those orbiting farther out feel more of the Sun's gravitational influence and less of the planet's. Eventually, there comes a point — the edge of the Hill sphere — where the Sun's effect begins to dominate. Beyond this distance, a moon cannot stably orbit the planet. Instead, it will slip away and follow its own path around the Sun.

The size of a planet's Hill sphere depends both on the planet's mass and its distance from the Sun. A large planet like Jupiter reigns gravitationally supreme over a vast region of space, while a small planet such as Mars has a much lesser sphere of influence. For planets with equal masses, those closer to the Sun have smaller Hill spheres than those orbiting farther away.

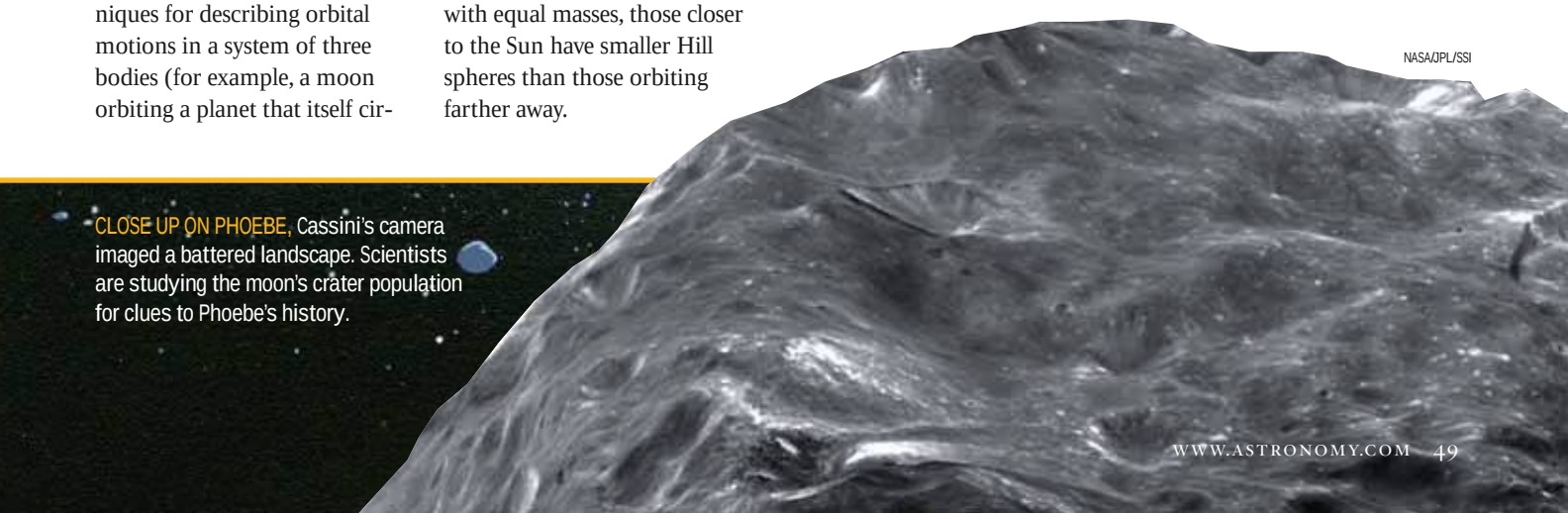
Searching space

As seen from Earth, the areas of sky covered by the Hill spheres of Jupiter, Saturn, Uranus, and Neptune are 48, 22, 6, and 7 square degrees, respectively. These are small compared to the 41,000-square-degree area of the full sky that an *in situ* spacecraft would have to search.

But ground-based observers still have to stitch together a lot of quarter-square-degree images to cover a planet's entire Hill sphere. This is one practical reason why Gladman's team focused its initial satellite searches on the neighborhoods of Uranus and Neptune rather than Jupiter and Saturn.

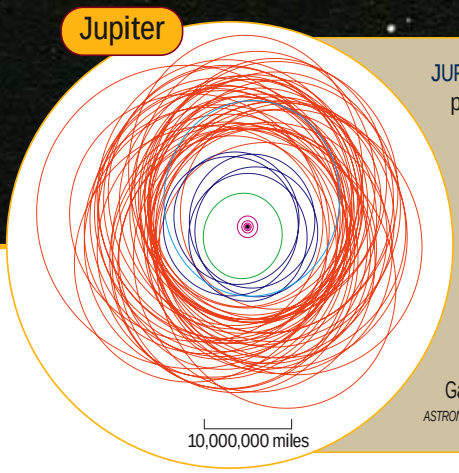
Investigating the most distant planets comes with a price, though. The moons of far-off planets shine more faintly and are more difficult to spot than those nearby because the sunlight they reflect drops off rapidly with increasing distance from the Sun. For example, a 1-mile-diameter moon orbiting Jupiter appears as bright as a 4-mile moon at Saturn, a 16-mile moon at Uranus, and a 36-mile moon at Neptune.

Of the 75 new moons discovered over the last several years, most are smaller than about 6 miles across. The largest of the new satellites is 120-mile-diameter (190 kilometer) Sycorax orbiting Uranus, while the smallest new satellites, spotted at Jupiter, are barely half a mile across.



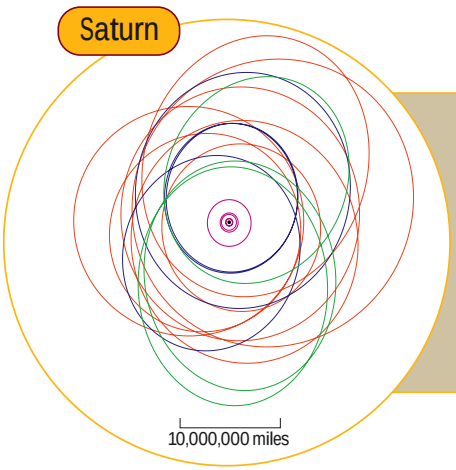
NASA/JPL/SSI

CLOSE UP ON PHOEBE, Cassini's camera imaged a battered landscape. Scientists are studying the moon's crater population for clues to Phoebe's history.

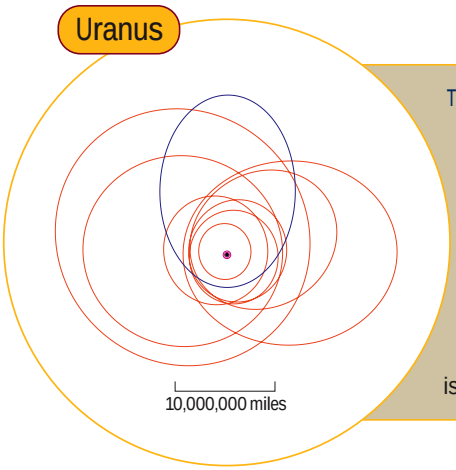


JUPITER'S MOONS wrap the planet in an ever-shifting orbital network. The orbits in red go retrograde — clockwise as seen here — unlike the regular moons (other colors) that orbit in the same direction Jupiter rotates. The innermost (pink) orbits belong to Io, Europa, Ganymede, and Callisto.

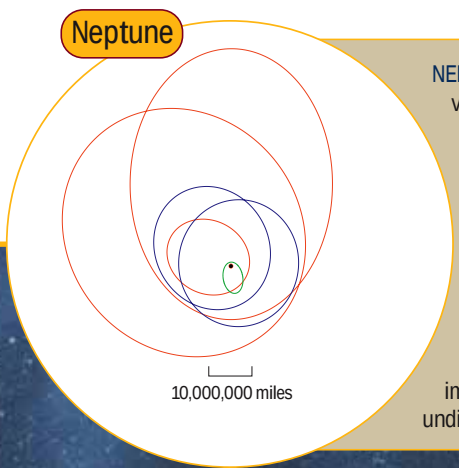
ASTRONOMY: ROEN KELLY/SCOTT SHEPPARD, CIW



THE SATURNIAN IRREGULAR MOONS belong to several groups (coded by color). The outermost pink orbit is that of Iapetus. Note the large gap between Iapetus and the innermost irregular moons.



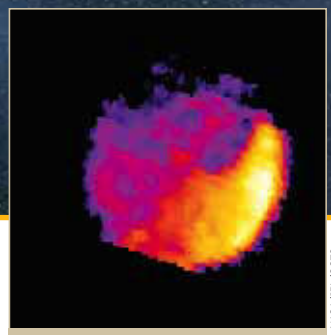
THE IRREGULAR MOONS OF URANUS weave a loose pattern around the regular moons, shown in pink. Although Uranus has only a sixth the mass of Saturn, its moon swarm reaches about as far into space because the Sun's gravity is weaker there.



NEPTUNE'S MOONS include 7 vagabonds and 6 regulars close to the planet. The small number comes from search difficulties caused by Neptune's distance from Earth. Its Hill sphere spans more than twice Jupiter's, and Neptune orbits near the Kuiper Belt of icy planetesimals. It could have many undiscovered moons.

NASA/JPL/UNIV. ARIZONA

PHOEBE'S SURFACE displays a variety of materials as mapped by Cassini's spectrometers. Exposures of water ice appear blue, carbonaceous material is red, and a second carbonaceous "mystery material" (not yet identified) appears green.



NASA/JPL/GSFC

COLD DOMINATES the surface of Phoebe, which has a peak temperature of 107 kelvins (–267° Fahrenheit), shown in white. The coldest temperature Cassini detected (purple) was found on the nightside: 75 kelvins, or –324° F.

Patterns in the sky

The flurry of new satellite discoveries (75 in all) reveals some patterns that planetary scientists are using to probe the outer solar system's history.

Nearly two-thirds of the known moons, including all the recent discoveries, are irregular satellites. These orbit far from their planets along highly tilted, elliptical paths. (Many irregulars also orbit retrograde, opposite the direction followed by the planets themselves.)

In particular, the orbital distributions of Jupiter and Saturn's irregular moons hint at past interactions and collisions. When the giant planets were forming, dense envelopes of gas surrounded each, feeding the growing bodies. Asteroidal objects born elsewhere in the solar system flew closely past the embryonic planets. Encountering the gas, they were slowed by friction, and at least some became captured. Collisions among these vagabond moons subsequently thinned their numbers and left the planets with orbiting fragments for scientists to study today.

For example, at Jupiter, all but one of the newly found irregular objects orbit retrograde. At Saturn, however, distant prograde and retrograde moons appear in roughly equal numbers. Furthermore, their orbital tilts are not random: They're grouped into associations that imply a common origin for a group's members.

The associations resemble the minor-planet families in the main asteroid belt, which are the remains of large parent bodies that broke apart ages ago.

Another pattern is that none of the 75 new moons circles a terrestrial planet. (One search of Mars' Hill sphere would have found any undiscovered inner satellite bigger than 100 yards across.) This comes as no surprise. Terrestrial planets orbit

the Sun more closely than the gas giants (thus reducing their Hill spheres' extent), and even the most massive terrestrial planet (Earth) has only 7 percent the mass of the lightest gas giant (Uranus). Small masses plus solar proximity equals small Hill spheres.

Yet the real picture is a little more complicated. Terrestrial planets actually can have a kind of vagabond moon. Recent theoretical and computational work has turned up asteroids that are not currently satellites of the terrestrial planets — but which have been in the past and will be again in the future. Most of these are natural objects, asteroids that wandered into the inner solar system and were temporarily captured.

At least one, however, is almost certainly artificial. In September 2002, amateur observer Bill Yeung discovered an unusual, fast-moving object near Earth that appeared to be orbiting our planet about twice as far away as the Moon.

At first, it seemed J002E3 was the only known case of a small asteroid captured into orbit around Earth. But analysis of its pre-capture orbit and solar-radiation pressure's effects on its trajectory proved that J002E3 is manmade. It's the S-IVB third stage from Apollo 12, which returned home after a 33-year "walkabout" through the inner solar system.

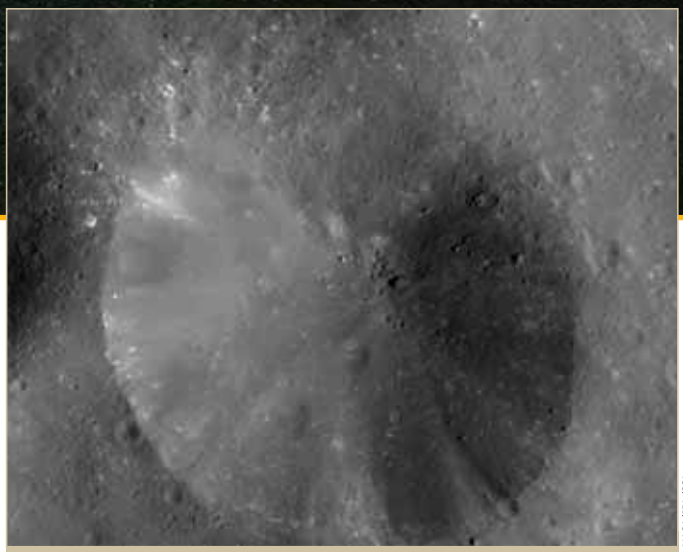
Close-up views

To scientists, the wayward moons of the outer solar system have long been just featureless points of light circling distant planets. Yet this picture began to change June 11, 2004, when the Cassini spacecraft, en route to arrive at Saturn 3 weeks later, flew past the planet's tiny, irregular moon Phoebe.

Cassini's instruments revealed a unique and alien world, potato-shaped and heavily crater-pocked. Dark organic material overlies a buried icy layer partly exposed to view inside deep-penetrating craters. Cassini spotted bright streaks and rays associated with craters, and found long grooves and other linear features.

Phoebe's density is 1.6 times that of water, a low value implying large amounts of ice and, perhaps, a somewhat porous exterior. Oddly (and probably coincidentally), Phoebe's rotation period, 9 hours and 16 minutes, gives it a day not much different than Saturn's.

Scientists looking to unravel the origins of irregular satellites are focusing closely on Phoebe's crater population. These scars from ancient impacts give a glimpse into this mysterious object's violent past.



NASA/JPL/SSI

GEOLOGICAL DETAILS APPEAR in this 8-mile-diameter (13 km) crater on Phoebe — building-size boulders litter the crater's floor, while bright splashes mark recent impacts and landslides. Scientists hope such details will help them better understand Kuiper Belt objects.

Some craters came from comets passing through the saturnian system, while others may have come from material in orbit around Saturn. The five additional small moonlets in Phoebe's family came from at least one large impact, evidence of which may still be visible on Phoebe's surface. What fraction of the moonlets created in such a titanic event came back one day — billions of years later — to reimpact its parent satellite? How many will do so in the distant future?

Cassini won't return to survey Phoebe again — it lies too far from the spacecraft's trajectory for the rest of the mission. But scientists studying irregular moons have another target in mind for an upcoming mission.

The New Horizons mission to Pluto and the Kuiper Belt is scheduled to launch in January 2006. In February 2007, the spacecraft will attempt a close flyby of one of Jupiter's small irregular satellites. If successful, this will bring into close-up focus another distant point of light in the sky.

The irregular moons of the giant planets are the hoboes of the Hill sphere — vagabonds that come and go as dictated by gravity. With origins far from their present homes, they intrigue scientists with the messages they bring from distant parts of the solar system. Studying them in detail will give us a better look at how the planetary system we call our own was born.

Find out how planetary scientists study vagabond moons and their origins at www.astronomy.com/toc

/// MOONS, VAGABOND AND OTHERWISE

PLANET	REGULAR MOONS	IRREGULAR MOONS	TOTAL MOONS
Jupiter	8	55	63
Saturn	19	14	33
Uranus	18	9	27
Neptune	6	7	13

BY MARTIN RATCLIFFE AND ALISTER LING

MAY 05

Complementing the Moon's packed schedule of events this month, several planets, comets, asteroids, and galaxies strut their stuff.

A month of shadows

Deep-sky observers have many splendors

to see — galaxies, nebulae, and star clusters are timeless to our eyes. If you miss an object this month, rest assured, you can look for it the next. In contrast, the dynamic movements in our solar system open up a new realm of experience for the backyard astronomer. Nothing ever quite repeats, so every event is special in its own way.

One consequence of the motion in our neighborhood is the ever-changing shadow-play of planets, moons, and asteroids. Saturn owes at least some of its appeal to the 3-D appearance it gains when the planet's shadow falls on the rings. Get a good look at Saturn now — by the end of June, it will be lost in the Sun's glare.

The Galilean moons of Jupiter also entertain as they travel around the planet. Just about every other night, one of the moons casts an ink-black shadow onto the gas giant's swirling cloud tops. A handful of times each month, two moons simultaneously cast shadows on Jupiter. The two best events for North American observers this month come the evenings of May 19 and 26.

The first reasonably accurate estimate of the speed of light came in the 1600s, when Danish astronomer Ole Rømer timed similar shadow events when Jupiter was different distances from Earth. The flip side to watching the Galilean moons' clockwork rhythms comes in observing a moon slowly emerge from, or disappear into, Jupiter's shadow.

TOM MARTINEZ

THE MOON COVERS ANTARES for North American observers May 24. The Moon will be nearly full, not a crescent as in this 1991 event.

Stars regularly cast the Moon's shadow onto Earth. Usually, we think of it the other way around — as the Moon hiding a star — and call the phenomenon an occultation. The best event this month happens the morning of May 24 and involves the red supergiant star Antares. This star is so bloated that instead of vanishing instantaneously behind the lunar limb as most stars do, it fades quickly.

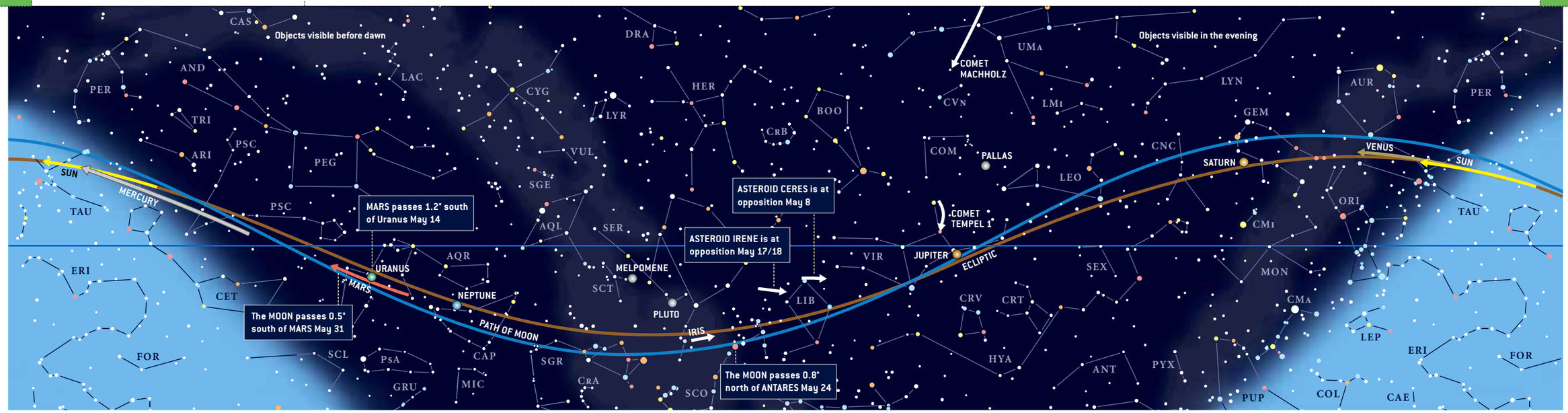
Some of the most dramatic shadows are cast by the mountains and crater rims of the lunar surface. Pick any time a couple of days from Full Moon (May 23) and look closely at the terminator, the line that divides darkness from light. Find a shadow next to an obvious feature, then come back every 10 minutes or so to see how much it has retreated. After full phase, the shadows grow longer.

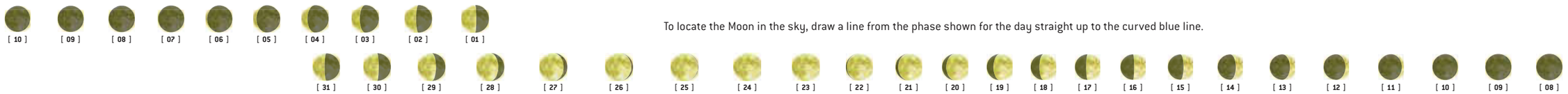
The best views of the night sky come from locations far removed from the light pollution of big cities. From the countryside, a small telescope can deliver a nice view of Comet C/2004 Q2 (Machholz). Watch Machholz over the course of May, as it slowly crosses the Big Dipper's handle. The comet glows around 9th magnitude, brighter than most of the distant galaxies that pepper this region of sky.

Dust freed from a comet's dirty-snowball surface forms a yellow-white tail. With each passage around the Sun, a periodic comet like 1P/Halley slowly spreads a stream of microscopic debris along its orbit. If Earth cuts across this path, the tiny meteoroids blaze trails across the sky, collectively creating a meteor shower. That's what happens in the predawn hours of May 4/5, when the dusty children of Comet Halley produce the Eta Aquarid meteor shower. Under a dark sky, expect to see 10 to 20 meteors per hour. The waning crescent Moon will not interfere much.

Planets this month

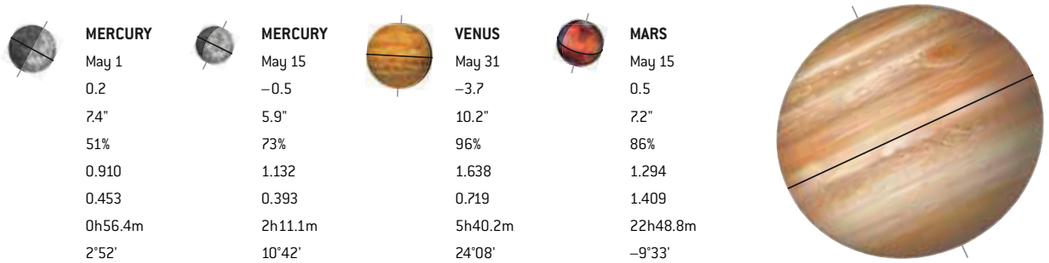
This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.





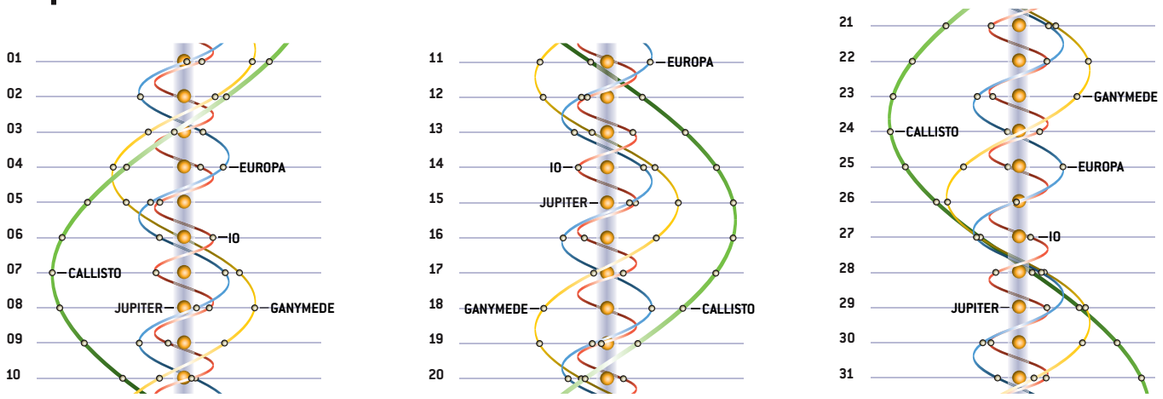
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	May 1	May 15	May 31	May 15	May 15	May 15	May 15	May 15	May 15
Magnitude	0.2	–0.5	–3.7	0.5	–2.3	0.2	5.9	7.9	13.8
Angular size	7.4"	5.9"	10.2"	7.2"	42.0"	17.4"	3.5"	2.3"	0.1"
Illumination	51%	73%	96%	86%	100%	100%	100%	100%	100%
Distance (AU) from Earth	0.910	1.132	1.638	1.294	4.691	9.558	20.322	29.929	30.077
Distance (AU) from Sun	0.453	0.393	0.719	1.409	5.456	9.073	20.065	30.063	30.950
Right ascension (2000.0)	0h56.4m	2h11.1m	5h40.2m	22h48.8m	12h37.4m	7h38.7m	22h48.4m	21h20.0m	17h34.8m
Declination (2000.0)	2°52'	10°42'	24°08'	–9°33'	–2°23'	21°42'	–8°24"	–15°42'	–15°00'



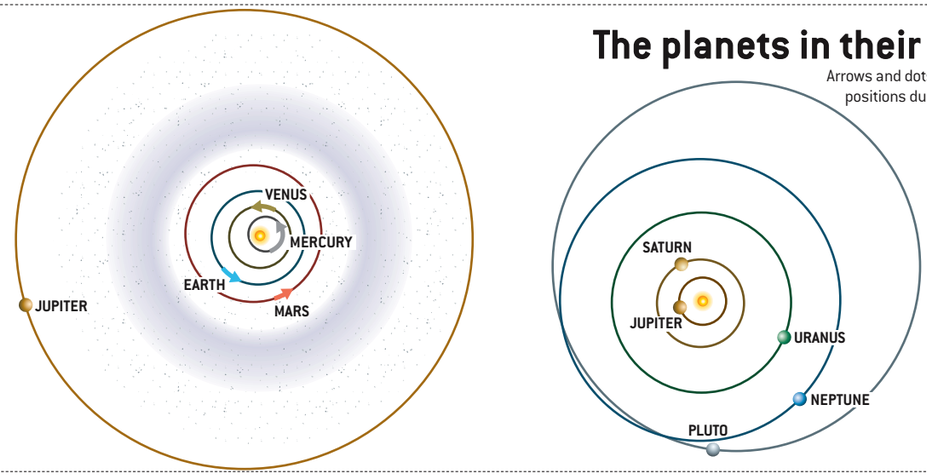
Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on date shown. South is at top to match the view through a telescope.



The planets in their orbits

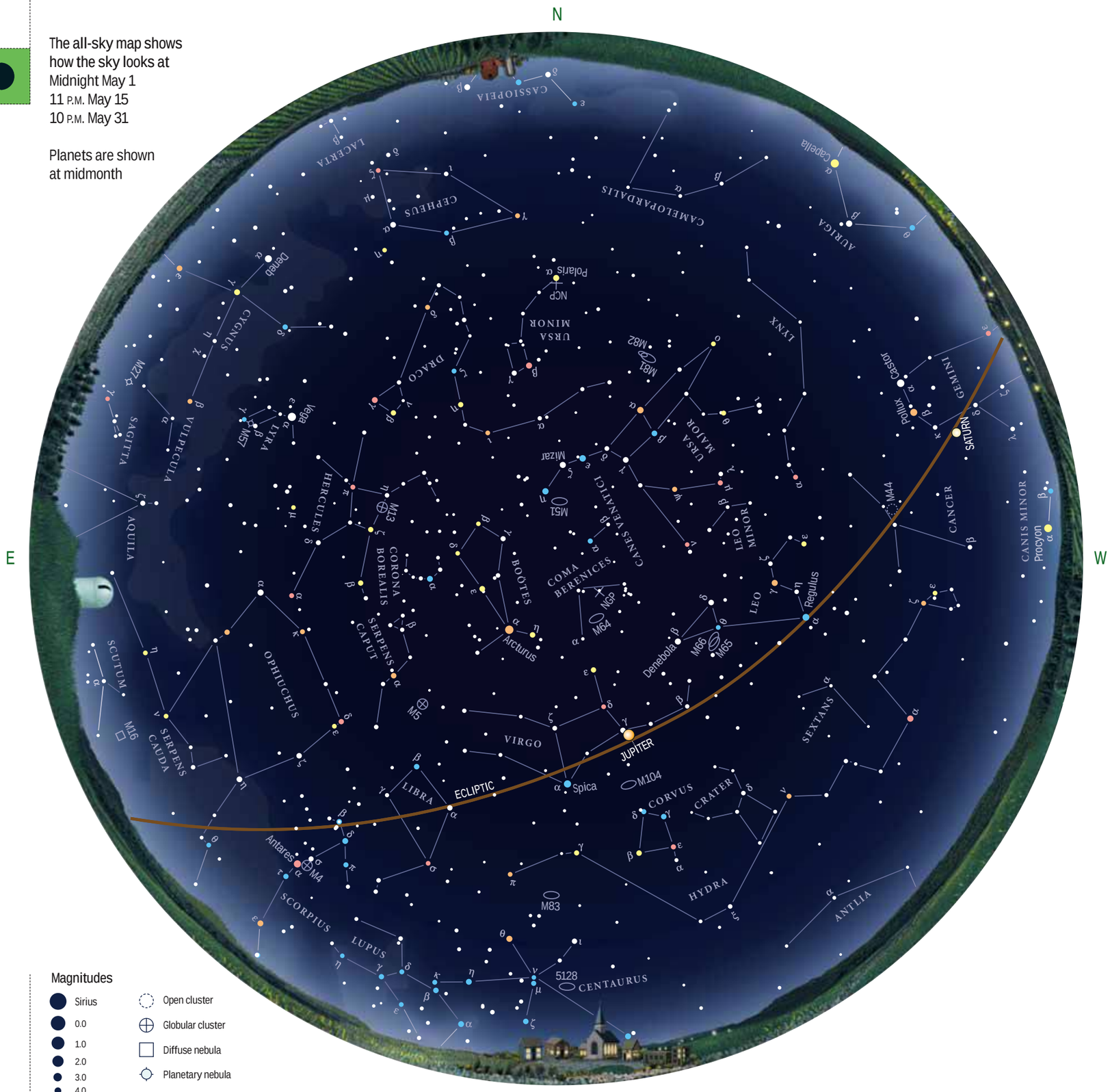
Arrows and dots show planets' positions during the month.



may 05

The all-sky map shows how the sky looks at
Midnight May 1
11 P.M. May 15
10 P.M. May 31

Planets are shown at midmonth



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

This map portrays the sky as seen near 35° north latitude at times shown in the upper left corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
[01]	[02]	[03]	[04]	[05]	[06]	[07]
[08]	[09]	[10]	[11]	[12]	[13]	[14]
[15]	[16]	[17]	[18]	[19]	[20]	[21]
[22]	[23]	[24]	[25]	[26]	[27]	[28]
[29]	[30]	[31]				

01 Last Quarter Moon is at 2:24 A.M. EDT

The Moon passes 5° south of Neptune, 11 A.M. EDT

02 The Moon passes 3° south of Mars, 11 A.M. EDT

03 The Moon passes 3° south of Uranus, 2 A.M. EDT

04 Eta Aquarid meteor shower peaks

06 The Moon passes 3° north of Mercury, 6 A.M. EDT

08 New Moon is at 4:45 A.M. EDT

Asteroid Ceres is at opposition, 2 P.M. EDT

10 Asteroid Vesta is in conjunction with the Sun, 11 P.M. EDT

13 The Moon passes 5° north of Saturn, 9 A.M. EDT

14 The Moon is at apogee (251,407 miles from Earth), 9:41 A.M. EDT

14 Mars passes 1.2° south of Uranus, 4 P.M. EDT

16 First Quarter Moon is at 4:57 A.M. EDT

18 Asteroid Irene is at opposition, 2 A.M. EDT

19 The Moon passes 0.4° south of Jupiter, 6 P.M. EDT

23 Full Moon is at 4:18 P.M. EDT

24 The Moon passes 0.8° north of Antares, 4 A.M. EDT

26 The Moon is at perigee (226,329 miles from Earth), 6:42 A.M. EDT

28 The Moon passes 5° south of Neptune, 5 P.M. EDT

30 Last Quarter Moon is at 7:47 A.M. EDT

The Moon passes 3° south of Uranus, 8 A.M. EDT

31 The Moon passes 0.5° south of Mars, 5 A.M. EDT

For definitions of terms, visit www.astronomy.com/glossary

THE DEEP SKY

The diminutive constellation Coma Berenices boasts one of the largest star clusters in the sky — and a gorgeous edge-on spiral galaxy.

Big, beautiful cluster

Known since the days of antiquity, the Coma Star Cluster is one of the sky's most beautiful sights. This delightful group of stars, cataloged as Melotte 111, has been associated with several stories and myths through the ages. In the third century b.c., Greek astronomer Eratosthenes dubbed the group "Ariadne's Hair," after the courageous princess who helped Theseus find his way back through the maze after slaying the Minotaur.

From a rural site, this slightly misty collection of a dozen stars draws the eye to the relatively empty space between the tails of Leo the Lion and Ursa Major the Great Bear. Binoculars provide the perfect field of view to surround this 5°-wide clump with darkness while adding scores of fainter stars throughout.

Martin Ratcliffe *is former president of the International Planetarium Society.* Alister Ling *is a meteorologist for Environment Canada.*

Edge-on grandeur

One of the most beautiful galaxies in the sky lies a short hop from Melotte 111. Under a dark sky, a 4-inch scope shows NGC 4565 as a ghostly streak with a slight bulge in the middle. An 8- to 10-inch aperture will pull in the dark equatorial dust lane, which is analogous to the Great Rift of dark material that slices through the Milky Way. With good seeing conditions, the galaxy's core peeps just past the dark swath crossing the middle. If you find yourself at a star party with big telescopes, request a view of NGC 4565 — the sight will count as a lifetime observing top 10.

ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

COMA BERENICES lays claim to one of the largest star clusters (Melotte 111) and most beautiful galaxies (NGC 4565) in the sky.

W. A. TREMBLY, JR.

EDGE-ON SPIRAL NGC 4565 ranks among the finest galaxies visible through a typical backyard telescope.

To spy this gorgeous galaxy, simply place your scope on the wide double star 17 Comae Berenices, located in Melotte 111. Turn off your drive (if you have one), and come back 7 minutes later to find NGC 4565 centered in the field.

North Galactic Pole

Most star atlases plot a large, inviting plus sign in northern Coma Berenices with the label "NGP." Several years ago, a member of the Edmonton Astronomy Club had trouble seeing the "object" located at this position. Other observers came to his aid, suspecting a faint haze somewhere in the blank star field. The whole escapade ended in fits of laughter when the helpers realized they were searching for the North Galactic Pole, a quest equivalent to looking for the painted line on the ground marking Earth's equator.

Our galaxy has an equator, the central plane of the disk that includes the spiral arms. We see it painted across the sky in a large band — the Milky Way. Use your imagination to travel to the center of the galaxy, then head straight "up" from the plane. From Earth's point of view, this axis points to a spot not far from the Coma Star Cluster. (In the same way, Earth's rotation axis points near the star Polaris.)

In May, it's easiest to picture this around 10 p.m. local daylight time, when the galactic pole lies nearly overhead as seen from mid-northern latitudes. The Milky Way, which represents the galaxy's equator, then circles the horizon.

THE PLANETS

May evenings present rousing shows of the solar system's two largest planets. But top billing this month goes to an occultation of the bright star Antares by the Moon.

Jupiter and Saturn make fine targets for evening viewing throughout May. Both planets appear as soon as the sky darkens. Saturn shines at magnitude 0.2 and stands high in the west, to the lower left of the two bright stars of Gemini the Twins. Watch for the visiting crescent Moon May 13. Saturn lies 7° directly below it.

This is the last month of 2005 to get a good view of Saturn in the evening sky. Next month, it will be visible in twilight only. Through a telescope, Saturn sports an angular size of 17", while the rings span 39". Relative to Saturn, Earth lies more than 90° farther around its orbit. This gives us a nice side-on view and makes the planet's shadow falling on the far side of the rings visible.

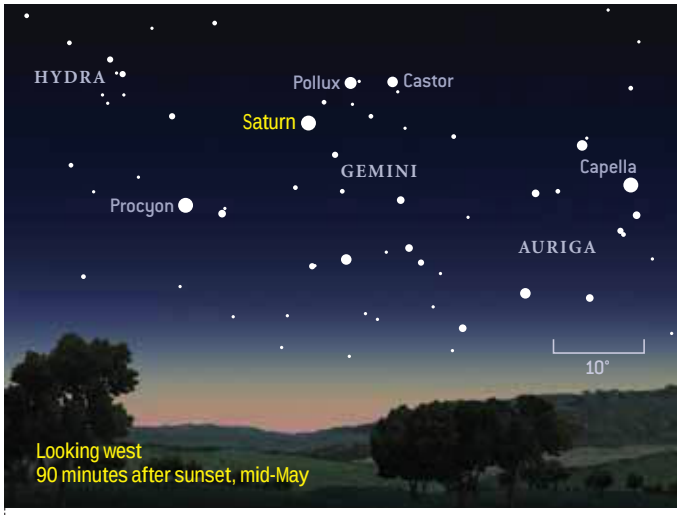
Saturn's biggest and brightest moon, Titan, travels twice around the planet this month. You'll find it west of Saturn May 10 and 26 and east May 1 and 18. Titan passes north of the planet May 6 and 22 and south May 14 and 30. At magnitude 8.3, Titan is easy to see through any telescope.

From May 13 to 15, you can spy Titan moving past the fainter moon Iapetus, which orbits much farther from Saturn and so takes much longer to complete an orbit. Iapetus has a dual personality, with half its face dark and the other half bright. During May, its dark face turns more in our direction, so we see it fade. Iapetus glows at 10th magnitude to start the month, but it will fade to 12th magnitude by early June.

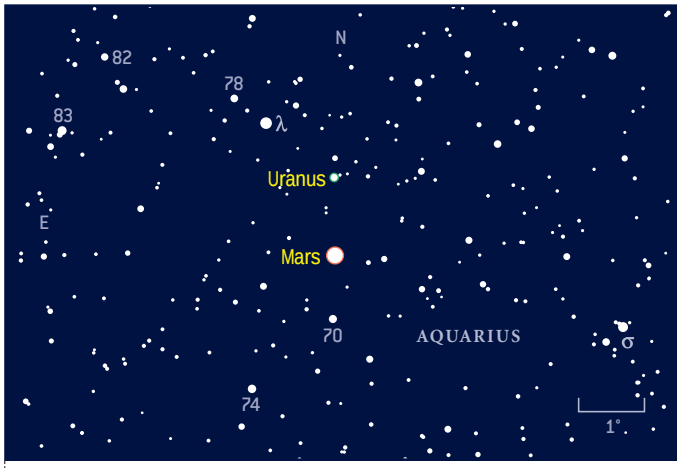
May offers one last good chance to view Saturn's other major moons, all of which lie much closer to Saturn than Titan or Iapetus. Tethys, Dione, and Rhea all glow around 10th magnitude and can be viewed with a small telescope. You'll need moderate aperture to spy 13th-magnitude Mimas and 14th-magnitude Enceladus, the innermost major moons.

While Saturn sinks slowly in the west, the solar system's largest planet, Jupiter, climbs high in the south. Jupiter lies near Porrima (Gamma [γ] Virginis) and about 15° from Virgo's brightest star, Spica. At magnitude –2.3, Jupiter shines more than 10 times brighter than Spica. Last month, Jupiter reached opposition, the peak of its 13-month-long apparition. But Jupiter lies far enough from Earth that its apparent size changes slowly, and the main observing period will continue for many weeks.

On the evening of May 19, you'll find Jupiter 3° from the gibbous Moon. Observers in much of South America will see the Moon occult Jupiter, but no such events are visible from North America during 2005. By the way, the Moon passes 2° from Spica the following night. Although no occultation occurs, a series will begin in September; the first one visible from North America arrives Christmas Day.



DON'T MISS YOUR LAST CHANCE of the year to get a nice, steady view of Saturn and its glorious rings in the evening sky.



MARS PASSES URANUS during the early morning hours of May 15, offering a great opportunity to locate the distant gas giant easily.

Jupiter appears 42" across in mid-May, a value that shrinks slightly as Earth continues to pull away from the giant planet. By the end of May, Jupiter lies more than 450 million miles from Earth, about 41 million miles farther than at April's opposition.

Jupiter offers something for everyone who views it through a telescope. Even beginners will notice the planet's squashed appearance: Its equatorial diameter measures 7-percent larger than its polar diameter. Another treat for novices is the dance of the four Galilean

moons. The relative positions of Io, Europa, Ganymede, and Callisto change nightly. Careful observers can even track the moons hourly.

The jovian atmosphere continues to entertain observers this month. The two dark equatorial belts prove most prominent. As your eye grows accustomed to viewing the bright disk, more subtle features will come into view.

Jupiter's equatorial region rotates in 9 hours and 50 minutes, while higher latitudes take 9 hours and 55 minutes to make it once around the planet. This 5-minute difference produces super-gale-force winds along the boundaries of adjacent regions. These areas abound with turbulent structures. Streaks of dark material injected into brighter surroundings create features with sharp contrast that are easy to track as Jupiter rotates.

The next planet to rise is **Pluto**, which lies 6 times farther from the Sun than Jupiter and glows dimly at 14th magnitude. Although Pluto's home constellation, Serpens Cauda, rises in midevening, wait until after midnight before trying to spot it. By then, the region lies high in a dark sky. Experienced observers with 6-inch telescopes have seen Pluto, but most people will need at least an 8-inch scope to spy this elusive quarry. Pluto lies 0.6° northwest of Xi (ξ) Serpentis May 1 and about twice as far away by the 31st. This 3.5-magnitude star serves as a convenient guide to the planet, but you'll still need a good star chart to pick out Pluto from the background.

Neptune is the next planet that becomes visible. It rises shortly before 3 a.m. local daylight time May 1, the same night the Last Quarter Moon lies 7° to its south. Neptune appears among the background stars of Capricornus the Sea Goat. Glowing at magnitude 7.9, it can be seen with binoculars if you know where to look. You'll need a telescope to spot its blue-gray disk, which measures 2.3" across. Neptune lies in the same finder field as 4th-magnitude Iota (ι) Capricorni; the planet is a mere 1.2° north-northwest of the star.

The next planet to rise is **Mars**, which pokes above the eastern horizon before 4 a.m. local daylight time. Mars lies in the constellation Aquarius, but it moves quickly — it will be banging on Pisces' door by month's end. On May 15, Mars and Uranus lie in the same binocular field. On May 31, a waning crescent Moon passes 0.5° south of Mars. Observers in the southern third of South America will see the Moon occult Mars then.

Mars has started to grow in apparent size as Earth gradually moves closer. Although features on the planet are still a challenge for small telescopes, that will change by the end of summer. All this is building to an excellent Mars opposition in early November. On May 15, Mars measures 7" across and shines at magnitude 0.5.

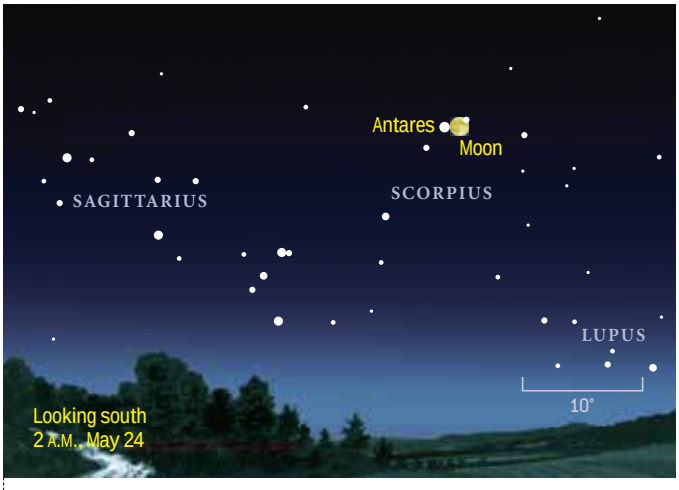
Mars spends mid-May in the company of **Uranus**. On the 15th, Uranus lies 1.2° north of the Red Planet. On the following few mornings, Uranus, Mars, and Lambda (λ) Aquarii form a neat triangle. Now rising 3 hours before the Sun, Uranus reaches a decent altitude before twilight robs our view. It glows at magnitude 5.9 and reveals a 3.5"-diameter disk through a telescope.

On the morning of May 24 (just as dawn brightens the sky on the East Coast, and around midnight on the West Coast), the Moon passes in front of the brightest star in Scorpius. Antares shines at magnitude 1.0 — bright enough that even the Full Moon won't drown out the star. You'll want to view the event through binoculars or a telescope.

Northern Hemisphere observers might glimpse **Mercury** during the first 2 weeks of May. Your best bet comes the morning of the 6th, when a waning crescent Moon lies near the planet. Mercury stands 3° to the lower right of the slender crescent as they rise shortly after 5 a.m. local daylight time, just an hour before sunrise. Mercury shines at magnitude 0.0, but you'll need an eastern horizon clear of obstructions to spot it.

/// ANTARES OCCULTATION (MAY 23/24)

City	Disappearance	Reappearance
Boston	4:23 A.M. EDT	not visible
Chicago	3:02 A.M. CDT	4:00 A.M. CDT
Denver	1:27 A.M. MDT	2:34 A.M. MDT
Los Angeles	11:56 P.M. PDT	1:16 A.M. PDT
Miami	4:23 A.M. EDT	5:37 A.M. EDT
New Orleans	3:01 A.M. CDT	4:17 A.M. CDT
San Francisco	11:50 P.M. PDT	1:06 A.M. PDT
Seattle	11:57 P.M. PDT	1:02 A.M. PDT
Tucson	12:11 A.M. MST	1:33 A.M. MST



THE RED SUPERGIANT STAR ANTARES will be blocked from view by the Moon during the early morning hours of May 24.

METEORS AND MOONS

A nearly moonless sky will give observers decent views of Comet Halley's detritus. A waning gibbous Moon is the best phase to examine the prominent rille inside the lunar crater Petavius.

Halley's remains

The peak of the annual Eta Aquarid meteor shower arrives the night of May 4/5. The shower's radiant — the point from which the meteors appear to originate — lies near the 4th-magnitude star Eta (η) Aquarii. In the early morning hours of May 5, the waning crescent Moon rises about 2 hours after the radiant. The 10-percent-lit crescent won't drown out many meteors.

The Eta Aquarid shower is one of two annual meteor showers associated with debris released by Comet 1P/Halley. (The other is the October Orionids.) During its countless passages around the Sun, Halley's nucleus has ejected tons of dust particles. When Earth runs into this debris stream every May and October, friction with molecules in our atmosphere causes the particles to flare into incandescence, creating the streaks of light we call meteors.

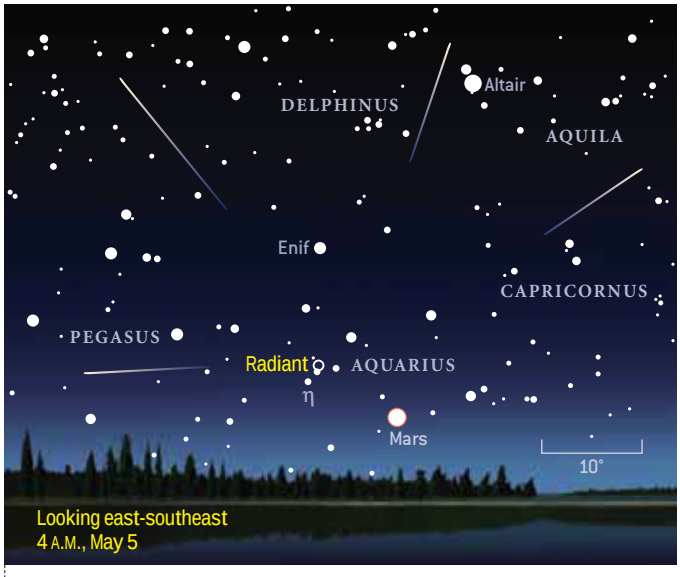
If you observed the Eta Aquarid shower under a dark sky with the radiant overhead, you could expect to see up to 60 meteors per hour. Unfortunately, from the Northern Hemisphere at least, the radiant never gets high, and observed rates typically run a more modest 10 to 20 meteors per hour. The radiant climbs much higher for those in the Southern Hemisphere, however, where this shower ranks among the best of the year. Eta Aquarid meteors tend to be swift, slamming into the atmosphere at 145,000 mph, and leave persistent trains, so it's worth getting up early May 5 to take a look.

Petavius and its rille

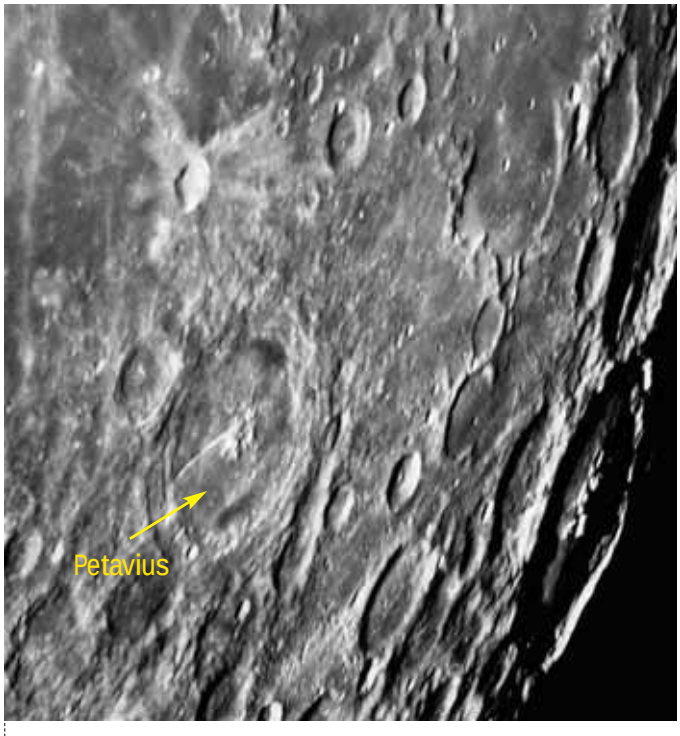
The huge crater Petavius lies near the Moon's eastern limb, where it becomes one of the first large craters visible after New Moon. Petavius stands near the southern shore of Mare Fecunditatis, which itself lies just south of the familiar Mare Crisium. The crater spans 110 miles, but it appears greatly foreshortened because it lies so near the Moon's limb.

The most obvious features within Petavius are the inner terraced walls and a dramatic linear feature that stretches from the central mountain complex to the southwestern wall. This latter feature is one of the most prominent rilles visible in small telescopes. It appears as a dramatic white streak shortly after Full Moon as the Sun sets over the crater. (This month, the best views come May 24 and 25.)

With good seeing conditions and high magnification, a small telescope reveals detail in the rille. Petavius appears to have two crater walls near the spot where the rille reaches the crater's rim. The central mountain range rises a mile above the surrounding floor. Petavius belongs to a fairly prominent crater chain, which includes Furnerius to the south and Vendelinus to the north.



ETA AQUARID METEORS, which peak the morning of May 5 this year, appear to emanate from a spot in the constellation Aquarius.



FROM *CONSOLIDATED LUNAR ATLAS* (LPL/UA)

LUNAR CRATER PETAVIUS (arrow) features a bright linear rille that runs from the crater's central mountain complex to the southwestern wall.

COMETS AND ASTEROIDS

Our lucky streak of reasonably bright comets and well-placed asteroids appears destined to continue for several months.

All night long

Rivaling many of the brighter galaxies in the Messier catalog, Comet C/2004 Q2 (Machholz) glows at a modest 9th magnitude this month. Under a dark sky, it should be just visible through binoculars, although a telescope will provide you with a brighter, more detailed view.

Comet Machholz continues to recede from both the Sun and Earth, crossing the handle of the Big Dipper into Canes Venatici the Hunting Dogs in May. It's well-placed for most Northern Hemisphere observers: It lies nearly overhead, where it is least affected by atmospheric conditions and visible nearly all night long.

Finding Comet Machholz could be a little confusing this month because when you're pointing north, you need to use the finder chart upside-down from the way you normally do. While you're looking through the eyepiece, nudge the scope toward Polaris. The new part of the sky is north; line this up with north on the finder chart.

With medium power, you should notice the comet's tail appears shorter than it did last month. Look for a sharper edge on one side — it's where the solar wind pushes back the dust and gas. Compare the comet's structure with that of the spiral galaxy M109 just a few degrees away.

The second asteroid

A careful leap off Leo the Lion's back will land you in the vicinity of the asteroid 2 Pallas. Its number indicates it was the second object discovered in what is now known to be the asteroid belt. As such, it is relatively bright, glowing at 8th magnitude this month — within reach of a small scope from a suburban backyard.

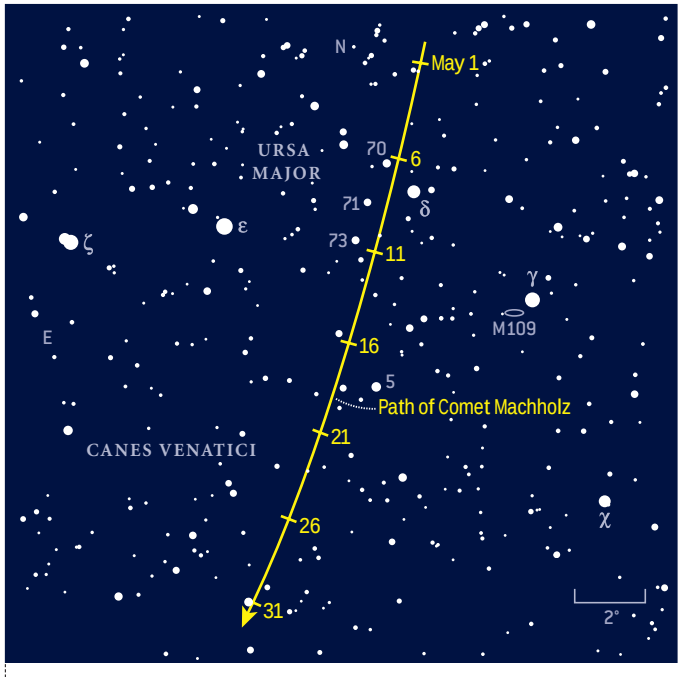
Start at the star 5 Comae Berenices, and slowly shift your scope toward the asteroid's position. The first "star" you see will most likely be Pallas itself. There are precious few other stars here because you are looking toward the galactic pole (see page 57), away from the populated core and equator of our Milky Way Galaxy.

From a dark-sky site, try for the 10th-magnitude globular star cluster NGC 4147 nearby.

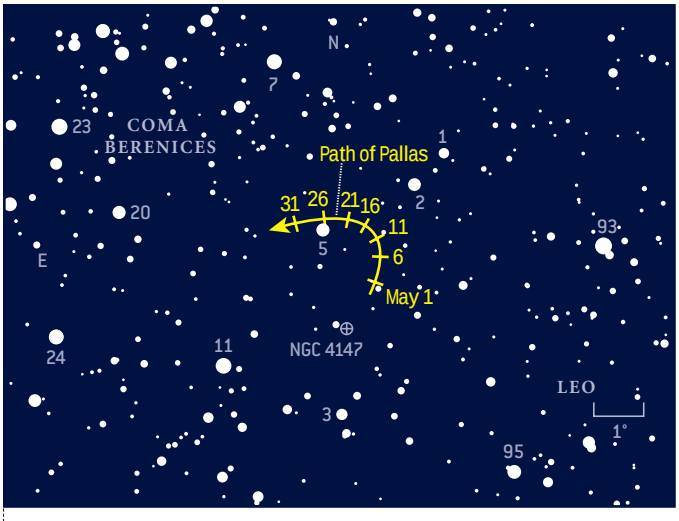
Shadow play

When an asteroid moves in front of a star, the rock literally casts its shadow along a narrow path on Earth's surface. The shape of the shadow reveals something about the shape of the asteroid, similar to the way a plane's shadow on a sunny day hints at its type. A widely spaced group of observers, timing the duration of the shadow's passage, can together determine this shape.

The International Occultation Timing Association (IOTA) provides predictions for these events on its web site: *www.lunar-occultations.com/iota*. Look for a path that crosses your area and give it a try. With only your eyes, a tape recorder, and shortwave radio, you can make a scientifically useful observation. There are links on IOTA's web site on how to do this.



COMET MACHHOLZ plies the handle of the Big Dipper during the first half of May. It dips into Canes Venatici late in the month.



ASTEROID PALLAS lies in a star-poor region of Coma Berenices this month, making the quest to spot it easier than normal.

Near the end of the Big Dipper's handle lurks M101, a delightful celestial pinwheel. /// BY ALAN GOLDSTEIN

A spiral masterpiece

Amateur astronomers take note:

Currently, a cosmic jewel — M101, the great spiral galaxy in Ursa Major the Great Bear — rides high in the northern sky. M101's striking appearance rewards the casual observer. It also rewards a more dedicated observer because once you go beyond its overall beauty, the amount of detail is amazing.

Ursa Major holds many bright galaxies. In the 18th century, Charles Messier and Pierre Méchain observed M81, M82, M101, M108, and M109 there. Although all were given Messier (M) numbers, it was Méchain who discovered M101, early in 1781. It is a fascinating galaxy to observe because it shows much detail through 6- to 8-inch telescopes — the size many amateur astronomers use.

M101 (also known as NGC 5457) is a face-on spiral galaxy classified SAc — a normal spiral without any hint of a bar emanating from its small, central hub.

M101's spiral arms are open and narrow. As a result, it has a low surface brightness and looks fainter than the Whirlpool Galaxy (M51), 9° to the southwest.

MIKE PIERCE, JOHN JURCEVIC (INDIANA)/WIYN/NOAO/NSF

A SOUTHERN SECTION OF M101 reveals the galaxy's brilliant core and lots of detail within its spiral arms. Astronomers created this false-color image from a combination of red and near-infrared images.

Under a dark, transparent sky, the ghostly M101 is visible through large binoculars. Amid light pollution, you may glimpse the tiny, central hub of M101, but the disk and arms will prove elusive.

Sizing up M101

Look for M101 at the apex of a triangle approximately 4¾° from Mizar (Zeta [ζ] Ursae Majoris) and 5½° from Alkaid (Eta [η] Ursae Majoris), both of which lie in the handle of the Big Dipper. The spiral galaxy glows at 8th magnitude. Its low overall surface brightness makes it more challenging than a similar-magnitude galaxy that has thicker arms or a greater inclination to us, either of which would give a greater overall surface brightness.

M101 is nearly face-on, tilted a mere 18° to our line of sight. At 27' wide, it's nearly a Full Moon's diameter. Its large size and open arms reveal lots of detail.

M101 lies fairly close to us — 27 million light-years away. It's the largest member of a group of about a dozen galaxies. Most are small, low-mass objects similar to the Magellanic Clouds, which orbit the Milky Way. By measuring M101's apparent size and distance, astronomers calculated this spiral is about 170,000 light-years in diameter. In comparison, our Milky Way is about 100,000 light-years across.

The M101 group of galaxies (see "The M101 Group" on page 65) stretches across more than 10° of sky. Four are easy targets with telescopes 4 to 6 inches in aperture. Another three are suited for 8- to 10-inch scopes. The rest need to be viewed through 12- to 20-inch telescopes.

MIKE PIERCE, JOHN JURCEVIC (INDIANA)/WIYN/NOAO/NSF

A NORTHERN SECTION OF M101 shows regions of star formation as clumps of bright points. Astronomers created this false-color image from a combination of red and near-infrared images.

Dissecting the spiral

The arm structure of M101 does not have the ideal, or "classic," symmetry seen in other spirals of the same class, like M74 or M100. M101's odd arm structure is typical in galaxies that have passed close to another galaxy because gravitational interaction between two galaxies distorts their arms.

American astronomer Halton Arp included M101 in his 1966 catalog of peculiar galaxies. Russia's B. A. Vorontsov-Vel'yaminov included it as VV344a in his 1959 catalog of interacting galaxies and as VV456 in his 1977 catalog.

The inner portions of the spiral arms are relatively normal. But by the time they have wrapped around 360°, some arms split away, while others reconnect with the inner part of the arm. On M101's north side, the arms stretch far out into space,

GEORGE JACOBY, BRUCE BOHANNON, MARK HANNA/NOAO/AURA/NSF

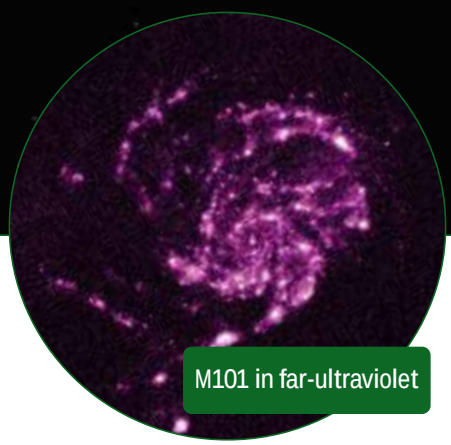
M101 (NGC 5457) in Ursa Major is one of a few face-on spirals easily visible to amateur astronomers. This image was taken through Kitt Peak National Observatory's 36-inch (0.9-meter) telescope using an 8-CCD-chip mosaic, which provides a wide field of view.

while on its south side, they abruptly end or wrap more closely to the inner arm structure. The whole picture suggests disturbance and disarray.

A number of nebular regions associated with M101 exist. William Herschel, the greatest 18th-century observer, noted three: NGC 5447, which lies at M101's southwest edge; NGC 5461, which lies southeast of the core; and NGC 5462, which lies a bit north of NGC 5461. Most of these nebulae (see the table on page 64) are visible with large amateur telescopes and are identifiable with a good star chart.

M101 in X ray

THE GLOWING BLOBS of M101 in this image belie the tremendous X-ray energy needed to create them. Areas marked with green diamonds may be a new class of X-ray source, with temperatures from 1 million to 4 million degrees Celsius. To obtain this false-color image, astronomers used the Chandra X-ray Observatory and made a 26.1-hour exposure of M101 in March 2000. NASA/CXC/SAO/R. DISTEFANO ET AL.



M101 in far-ultraviolet

THE FIRST FAR-ULTRAVIOLET IMAGE OF M101 was created by the Goddard Ultraviolet Imaging Telescope in 1995. This 22-minute exposure shows M101's spiral arms dotted with bright "beads" representing superclusters — massive concentrations — of young, hot, rapidly forming stars. The round blob to the lower left of M101 is NGC 5471, the brightest of M101's star-forming regions. JIM SAHLI/GODDARD SPACE FLIGHT CENTER

IN NEAR-INFRARED WAVELENGTHS, M101 has the same shape as in visible light. This image traces out the smoothly distributed, relatively old stars in M101. It shows how mass is distributed throughout the galaxy. 2MASS

ULTRAVIOLET EMISSIONS from M101 reveal hot stars only 10 million years old (colored blue) concentrated in the spiral arms and older stars nearer to the nucleus that formed more than 100 million years ago. GALEX

Observing the arm structure requires at least a 6-inch telescope, but a 10- or 12-inch scope may be more practical. Start with low power — remember, this is a large object you're trying to see all at once.

You'll see three spiral arms through a 6- or 8-inch telescope. Larger instruments will show the arms branching and the knotty structure of embedded gas clouds.

Associations of hot, blue type O and B stars are common in M101 and comparable to those in the Large Magellanic Cloud (LMC). CCD cameras can discern the most luminous stars. Some of the bright, irregular supergiant variable stars begin to resolve at visual magnitude 18.9. The brightest red supergiants start to be seen at magnitude 20.3.

Alan Goldstein *is the founder and coordinator of the National Deep-Sky Observers Society.*

HII regions

The face-on orientation of M101 is ideal for observing features in its spiral arms. Astronomer Paul Hodge and others have cataloged 1,264 HII regions in M101. HII regions are areas where hot, newly formed stars illuminate and excite clouds of hydrogen. Most of the brighter clouds are actually groups of nebulae. The typical HII region in a spiral galaxy is approximately 50 light-years across. The larger complexes are an order of magnitude bigger than this.

All of the giant HII regions in M101 are X-ray sources. In a 1999 study of NGC 5461, NGC 5462, and NGC 5471, astronomers determined high star-forming efficiency — not massive clouds — appears to be the prerequisite for the formation of the large number of stars whose radiation is required to produce the giant HII regions in M101.

The best way to see M101's HII regions is by using a nebula filter, which screws into an eyepiece's threads. The brightest HII regions can be enhanced with a UHC filter. This filter's effectiveness depends on your instrument's light-gathering ability and the quality of your observing site. The UHC filter will not help if the HII regions are invisible due to light pollution or if you are using a small telescope.

/// HII REGIONS IN M101

Object	R.A. (2000.0)	Dec. (2000.0)	Number of HII regions
NGC 5447	14h02m27.9s	54°16'35'	13
NGC 5449	14h02m27.27s	54°19'49'	8
NGC 5450	14h02m29.4s	54°16'16'	1[1]
NGC 5451	14h02m37.0s	54°21'45'	5
NGC 5453	14h02m56.4s	54°18'29'	14
NGC 5455	14h03m01.1s	54°14'29'	2
NGC 5458	14h03m12.4s	54°17'55'	21
NGC 5461	14h03m41.4s	54°19'05'	12
NGC 5462	14h03m53.0s	54°21'56'	33
NGC 5471	14h04m29.3s	54°23'47'	1[2]

1) Part of NGC 5447 complex

2) NGC 5471 is a single HII region that contains three supernova remnants.

Supernovae

Although only three supernovae have been reported in M101, it is likely (because of its face-on orientation) that another will be picked up in the next 20 years. If you aren't familiar with the field stars near M101, you'll find hunting supernovae in this large galaxy somewhat daunting. A number of 11th- to 13th-magnitude field stars (the peak supernova magnitude range) can be seen around M101.

The study of extragalactic supernova remnants is interesting but not of much practical value to the visual observer. These objects lie beyond the range of amateur telescopes, even those equipped with CCD cameras. Astronomers have found 93 supernova remnants within M101 because of high activity and the galaxy's face-on orientation. Some exceed 1,000 light-years in diameter, indicating they were formed from multiple supernova explosions.

Recent studies of NGC 5471 reveal three supernova remnant candidates, the brightest being the shell in NGC 5471B. This shell's mass is more than 4,000 times that of the Sun.

The nucleus

It's not unusual for a galaxy's bright nucleus to harbor explosive activity. Indeed, studies by J. W. Moody and his colleagues at Brigham Young University indicate that while most motion shows matter spiraling into M101's nucleus, an unstable area exists. Colliding gas is producing a high-temperature, high-density cloud. A blue arc emanates from the nucleus of M101, which may indicate a transition to a high level of explosive activity.

Evidence points to "geyser-like" eruptions every 22 million years from a black

ILLUSTRATIONS: ASTRONOMY: ROEN KELLY

M101 lies in Ursa Major. To find it, make a triangle with the two stars at the end of the Big Dipper's handle.

hole (with a mass just less than a million times that of the Sun) orbiting within M101's nucleus and sweeping up material from a bar-shaped molecular cloud.

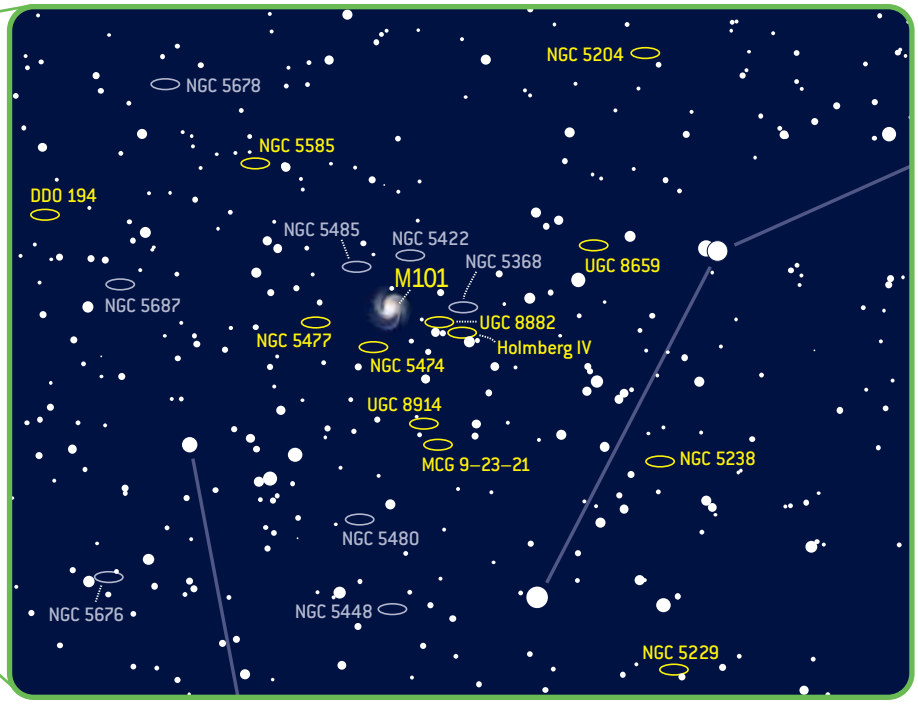
What can a visual observer see within the central region? Under a mediocre sky, the central hub is all that may be visible.

Now it's your turn

M101 is the nearest massive SAc-type galaxy, and it appears face-on, revealing a wide variety of features across its disk. It's an important galaxy for studies related to the cosmic distance scale. Indicators like Cepheid variable stars and planetary nebulae within this galaxy are resolvable with Hubble and large, ground-based, optical telescopes such as Keck I and II.

M101 is a stepping-stone to the massive Virgo galaxy cluster. M101 will surprise you with features both unique and common. Indeed, this galaxy has something to offer any observer interested in discovering the wonders of our universe.

NGC 5474 is a magnitude 10.8 spiral galaxy that is one of the brightest members of the M101 Group. NGC 5474 looks as it does because it is being gravitationally distended by M101, which lies nearby. ADAM BLOCK/NOAO/AURA/NSF



GALACTIC MEMBERS OF THE M101 GROUP (detailed in the table below) appear in yellow on this chart. Other field galaxies you'll run across while observing this area are in white. The area of sky pictured here spans 26° across and is approximately 11° high.

/// THE M101 GROUP

The Milky Way is part of a group of galaxies known as the Local Group. The largest member of the Local Group is the Andromeda Galaxy (M31). The Milky Way is next in size. Like our Local Group, the M101 Group is dominated by two large spirals: M101 and NGC 5585, a 10.7-magnitude member lying slightly more than 2° north of M101. Like our neighborhood, dwarf galaxies — low-mass spirals and irregulars — mainly populate the M101 Group.

Object[1]	R.A. (2000.0)	Dec. (2000.0)	Mag.[2]	Type[3]
NGC 5204	13h30m	58°25'	11.3v	SA
NGC 5229	13h34m	47°55'	13.7v	SBd
NGC 5238	13h35m	51°37'	13.4v	SABd
UGC 8659	13h40m	55°25'	16.0b	I
Holmberg IV	13h55m	53°54'	13.4v	IB
UGC 8882	13h57m	54°06'	15.3b	dE
MCG 9–23–21	13h58m	51°58'	16.0b	bcd
UGC 8914	13h59m	52°22'	16.0b	SA/I
M101	14h03m	54°21'	7.9v	SAc
NGC 5474	14h05m	53°40'	10.8v	SAcd (pec)
NGC 5477	14h06m	54°28'	14.0v	SA
NGC 5585	14h20m	56°44'	10.7v	SABd
DDO 194	14h35m	57°15'	14.5b	SA

1) Italicized number = possible member

2) b = blue magnitude, v = visual magnitude

3) SA = Normal spiral; SB = Barred spiral; SAB = Spiral with elongated hub; I = Irregular; d = Dwarf; E = Elliptical; bcd = Blue compact dwarf; pec = Peculiar

ASK ASTRO

Earth's future orbit, Sun and season, and asteroid gulf

EARTH'S FUTURE ORBIT

After our Sun dies, will the planets still orbit it?

— ROBERT BURKE, LAKEMOOR, ILLINOIS

In about 5 billion years, the Sun will exhaust its central supply of hydrogen, and it will swell into a red giant star, fusing hydrogen in a shell around a dead core of helium "ash." Eventually this core will ignite, and the Sun will shrink somewhat in size as it fuses helium into carbon and oxygen.

The Sun will quickly exhaust its helium and swell into a larger red giant as it enters its "asymptotic giant branch" phase. Matter more easily escapes the red giant Sun. Soon after becoming an asymptotic giant, the Sun will eject much of its remaining mass in a planetary nebula. It will leave behind a tiny white dwarf containing only about half the Sun's present mass.

So, what happens to the planets of the solar system as the Sun swells and loses mass? If the Sun were to lose half of its mass instantly, the planets would all fly off into deep space because the Sun's gravity would be too weak to retain them. This won't happen because the mass-loss processes described above occur over billions of years.

Although the planets will stay bound to the Sun, they will move farther away from it because of the Sun's decreased mass and weaker gravity. This phenomenon is known as adiabatic expansion of the planets' orbits.

The fate of the outer planets is pretty straightforward. Computer simulations show bodies from Jupiter out through the Kuiper Belt will remain bound to the white-dwarf Sun. They will orbit it for the billions of years it will take for the Sun's light to wane and, ultimately, fail completely.

The fate of the inner planets is less certain. Although the asymptotic giant Sun will bloat outward to near the current orbit of Mars, the Sun's mass loss will swell the orbits of the inner planets, too. Mercury will be swallowed by the Sun during its first red giant phase. Venus may survive the first phase, but will be consumed during the second giant phase. In all but the direst scenarios, Mars will survive the Sun's final stages of evolution.

Earth's fate depends on precise details of the Sun's evolution and mass loss, none of which are known. Earth will likely survive the Sun's first round of expansion; but in the second giant phase, the Sun's surface grazes Earth's final orbit. Because the Sun's outer layers will have low density, and because the giant phase lasts only a few million years, it's even possible Earth could end up orbiting inside the Sun without being completely destroyed. — KURTIS A. WILLIAMS, STEWARD OBSERVATORY, TUCSON, ARIZONA

ASTRONOMY: RICK JOHNSON AND ROEN KELLY

THE AGING SUN will lose about half its mass, which will loosen its gravitational grasp on everything in the solar system. Planetary orbits will expand in response. Mercury will be lost when the Sun first enters its red giant phase (middle panel), but Venus, Earth, and Mars will escape incineration. Later, when the Sun expands out to Mars' present orbit, Earth will graze its surface (bottom).

SUN AND SEASON

If the tilt of Earth's axis is the cause of the seasons, why don't the winter and summer temperature extremes occur at the solstices?

— JEROME BERKOWITZ, BRICK, NEW JERSEY

In the Northern Hemisphere, the highest average maximum temperatures associated with summer and the lowest average mini-

mum temperatures associated with winter follow the summer and winter solstices by about a month. This situation is often referred to as "seasonal lag."

The Sun supplies energy to Earth, which absorbs and reradiates some of that energy. Because of the Sun's high angle in summer, the amount of energy the Northern Hemisphere gains exceeds the energy it loses even after the summer solstice (June 21), when the number of daylight hours begins to diminish. This results in a continued warm-up — reflected in daily average temperatures — for roughly 30 days following the solstice.

Let's use Trenton, New Jersey, as a reference point. There, the average daily high/low near the summer solstice is 83°/63° F (28°/17° C). However, the maximum summer daily high/low temperatures peak at 86°/68° F (30°/20° C) between July 21 and July 23. The decrease in solar radiation after the summer solstice simply isn't significant enough to change the summer warming pattern until about 30 days later.

The opposite effect occurs at the winter solstice (December 21). Despite minor increases in solar radiation following the winter solstice — thanks to the Sun's gradually increasing altitude — the Northern Hemisphere's energy loss still exceeds the increase in solar energy, and cooler temperatures prevail for the next 30 to 45 days. The average daily minimum high/low on the winter solstice for Trenton is 41°/27° F (5°/–3° C). But the minimum winter daily temperatures — on average, a high/low of 35°/23° F (2°/–5° C) — don't occur until around January 30. — GRANT BROHM, METEOROLOGIST, MADISON, WISCONSIN

ASTRONOMY: ROEN KELLY

MAKING A CRATER as large as the Gulf of Mexico requires an asteroid between 50 and 100 miles (80 to 160 km) across — large enough to span the distance between the cities of Tampa and Orlando, Florida. An impacting asteroid is about 10 percent of the size of the crater it makes.

ASTEROID GULF

How large a body would it take to make a crater as wide as the Gulf of Mexico? — JIM BOWERS, NEWTOWN SQUARE, PENNSYLVANIA

The Gulf of Mexico is the result of plate tectonics, or "continental drift," in which the plates comprising the Earth's crust change position over time. The Gulf did not even exist in the distant past, and its size and shape will slowly change as time progresses and tectonic plates move.

To simplify matters, let's replace the Gulf with a perfectly circular sea having the same total area. The Gulf has an area of about 600,000 square miles (1,554,000 square kilometers), which means we can replace it with a circular sea 875 miles (1,410 km) across. Now, there are two ways to estimate the size of an impacting object from the size of the resulting crater. The first is an old rule of thumb: An asteroid or comet will make a crater about 10 times its size, or in this case, 87.5 miles (141 km).

A more rigorous approach is to adopt mathematical relations for crater size developed from nuclear weapons tests. With some assumptions on the ground composition, this will give us the explosive energy needed to make the crater, and we can translate this number into the body's size by assuming an impact speed. To form a Gulf-size crater in rocky soil, the energy required is 14 trillion megatons. If we assume an impact speed of 45,000 mph (72,000 km/h), the culprit body must be about 51 miles (32 km) across.

Both numbers are estimates. The rule-of-thumb approach ignores the body's impact speed, the composition of the ground at the place of impact, and the composition of the comet or asteroid, among other things.

The second method is designed to account for some of these variables, but it is based on nuclear tests with relatively small explosive yields — at least in comparison to the impact energies we're discussing — and there's no way to validate the results at such energies.

However, the fact that the two numbers are in the same ballpark suggests our estimates probably aren't too far off. So it would take a comet or asteroid between 50 and 100 miles (80 to 160 km) across to produce a crater the size of the Gulf of Mexico. — BILL COOKE, MARSHALL SPACE FLIGHT CENTER, HUNTSVILLE, ALABAMA

Not all of the Moon's "seas" are easily visible. Some lie buried beneath the lunar plains, covered by debris from later impacts. /// BY ROBERT BURNHAM

Sail a hidden sea

Most of the Moon's "seas," or maria, are so easy to spot you don't even need a telescope. Large, dark sheets of basaltic lava cover a sixth of the Moon's nearside. Filling shallow impact basins, they depict the cartoon face of the Man in the Moon. These highly visible maria, however, are simply the last lava the Moon gurgled out before its crust cooled and thickened enough to prevent further eruptions. While some craters pock the maria, on the whole, they lie largely undisturbed because no big impacts have struck since the lava ceased to flow around 2 billion years ago.

However, the visible maria are not the only ones the Moon has — in several places, ancient layers of lava lie buried by later deposits. Lunar scientists term these old lava sheets "cryptomare." One patch of cryptomare lies near the large crater Schickard in the southwest part of the nearside, where sunrise occurs a couple of days before Full Moon. Cyptomare often passes unnoticed by visual observers. Scientists spot it where a crater has dug through the covering layers and unearthed a splash of darker material or in places where the spectrum differs from the surrounding surface.

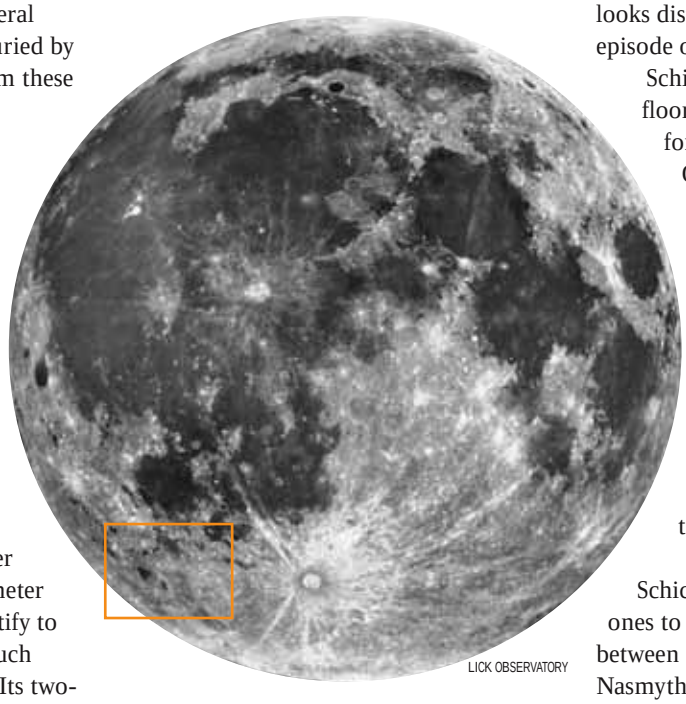
Let's start with the largest crater in the field, Schickard, with a diameter of 140 miles. Its battered walls testify to an ancient age, and it has been much degraded by subsequent impacts. Its two-tone floor, on the other hand, is relatively uncratered. On the Moon as elsewhere, such a fresh appearance with few craters points to a younger age.

Craters 5 to 10 miles across pepper the western part of Schickard's floor. With high magnification during moments of good seeing, you can spot even smaller ones in its eastern and northern sections. In the north and south, the floor itself looks distinctly darker, indicating an episode of lava flooding.

Schickard's appearance suggests the floor was smoothed after the crater formed. Then, ejecta from the Orientale impact basin covered the middle of the floor. This basin, centered about 950 miles to the northwest on the lunar farside, dates from approximately 3.84 billion years ago. It was the last major lunar basin to form, and the whole region here felt its effects.

The last stage flooded Schickard from below, emplacing the lava in the north and south.

Besides the craters inside Schickard, note the many similar-size ones to the west plus the crater clumps between Schickard and the nearby trio of Nasmyth, Phocylides, and Wargentin. Closely spaced and roughly strung in lines, these small craters are secondary impacts from Orientale that mark where high-flung debris pummeled the landscape.



LICK OBSERVATORY

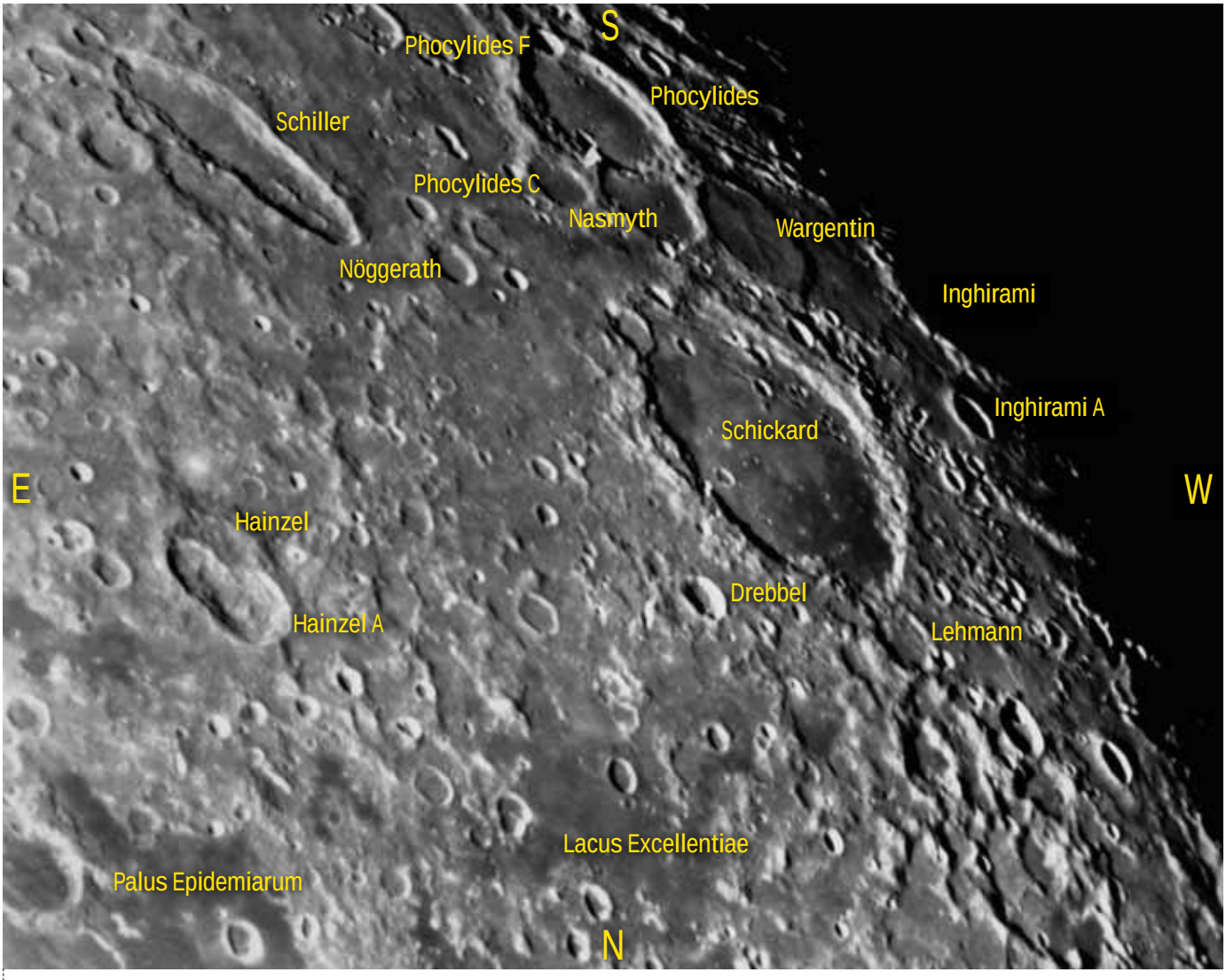
FIND SCHICKARD and its surroundings with the help of this locator map. The image is oriented as you see the Moon in the sky, with north at the top.

/// BEST DATES TO OBSERVE

Around lunar sunrise and sunset are good times to view the Moon because the low Sun casts shadows that reveal the most detail then. The best dates to observe the Schiller-Schickard area for the next 3 months are:

Lunar sunset
May 3–5, June 2–4, July 1–3

Lunar sunrise
May 20–22, June 19–21, July 18–20



CURIOUSLY SMOOTH for being in the Moon's southern highlands, the region around Schickard contains a buried lunar sea. South is at top.

This occurred right after a smooth layer of ejecta shooting out from the basin impact blanketed much of this area with light-tinted plains material.

Wargentin, 52 miles across, is a famous landmark. Sometimes dubbed the "brimful crater," it resembles an oval mesa with a smooth upper surface except for a ridge running down the middle that forks in the north. (The ridge disappears at high Sun angles.) The lava filling Wargentin may be related to the lava on Schickard's floor.

Phocylides (71 miles) and Nasmyth (48 miles) taken together resemble the imprint of a gigantic shoe. Phocylides shows a convex floor at low Sun angles. Both craters are ancient, showing fresh interior features such as central peaks or slumped terraces on their walls. Over these craters lies a mantle of Orientale debris also, and Phocylides F (15 miles) likely marks where a chunk of Orientale debris returned to slam down on the Moon.

The terminator in the image above roughly marks where the nubbly part of the Orientale debris, deposited close to the basin, grades into smoother ejecta lying farther away. The difference becomes more marked as the Sun rises higher and Inghirami (56 miles) emerges into daylight.

East from Phocylides lies the greatly elongated crater Schiller (44 by 110 miles). It looks like it too was created by debris from the Orientale basin impact. However, despite having its long axis aligned radially to Orientale, Schiller is not a merged line of secondary impacts from that basin. It is too old, 3.7 billion years at least, given the cratering on its floor. Instead, geologists think Schiller formed by an oblique blow that occurred before any major basins were born. This would date it to earlier than 3.92 billion years ago.

So where's the cryptomare? Everywhere here. If you cast your eye over this region, you see patches of mare showing in Palus Epidemiarum and Lacus Excellentiae. Less obviously, mare underlies much of the area seen here. Lunar scientists discovered the buried lava by noting craters that are surrounded by halos of ejecta darker than the surface material.

Impacts dredge up material from below, revealing otherwise hidden layers. If a crater is large enough, it may excavate all the way through the cryptomare to expose pre-mare terrain. Careful studies using spacecraft imagery, especially from Clementine, found that basaltic material underlies much of this entire region, and it averages about 1,800 feet thick.

Robert Burnham, *a senior editor of* Astronomy, *is the author of* Exploring the Starry Sky *(Cambridge University Press). He is working on a new book,* The Moon: a Telescopic Guide *(CUP).*

You'll be surprised by the great images you can create with a small telescope and webcam. /// BY DAMIAN A. PEACH

Small eyes on the sky

Many observers are familiar with the remarkable images being shot with webcams attached to large amateur telescopes. Gone are the days when hours of hard work — locked away in a darkroom after shooting three or four reels of film — were required to catch a few good frames of lunar craters or the planets. Today, imagers can obtain results of superior quality and capture a stunning level of resolution with just an 8-inch telescope. But what about those who own smaller apertures? Can they, too, produce such pleasing results?

How small is small?

It's no longer true that you need at least a 6-inch telescope to produce quality work you'll enjoy sharing with others.

With the use of webcam technology, what has become possible is amazing. Today, using a good quality 6-inch telescope, you can produce detailed views of Jupiter's clouds or the delicate markings on Mars. Even telescopes as small as 3 inches, equipped with webcams, can produce images you can study and compare to monitor changes — especially on the Sun, Moon, Mars, and Jupiter.

The telescope's quality is of vital importance. Because of their fine optics and sturdy construction, small apochromatic refractors can produce remarkable results, as can Maksutov reflecting telescopes. The latter type is especially attractive because you can buy these superb instruments at reasonable prices.

DAMIAN PEACH

THE AUTHOR'S SOLAR-IMAGING SETUP usually consists of a webcam attached to a filtered 3.2-inch Vixen apochromatic refractor. Webcam images are transferred directly to a computer. Later, the author processes and combines the best frames into a single image.

Just what is possible?

Figures often quoted as the resolving limits of telescopes apply only to point sources of equal brightness or to double star resolution. The most popular formula is the Dawes limit, which states the resolution in arcseconds is equal to 4.56 divided by the telescope's aperture in inches, or 11.58 divided by the aperture in centimeters. Planets are extended objects, so these values don't apply to planetary detail.

At the turn of the 20th century, famed astronomer William H. Pickering conducted experiments into the resolution of planetary detail. Pickering found that a dark spot on a bright background could be resolved to a level a little more than twice as good as the Dawes value. Perhaps the most famous example of this is the discovery of Saturn's Cassini Division made with a 2.5-inch refractor. This observation exceeds the Dawes limit by nearly a factor of 3 for this aperture. (The Cassini Division spans no more than 0.7" at any time, and the Dawes limit for a 2.5-inch telescope is 1.8".)

From this, it becomes clear that small apertures can produce high-resolution images when equipped with today's webcams. From my own images taken through a 3.2-inch apochromat, I've proved it is possible to exceed the 1" barrier on high-contrast lunar or planetary detail.

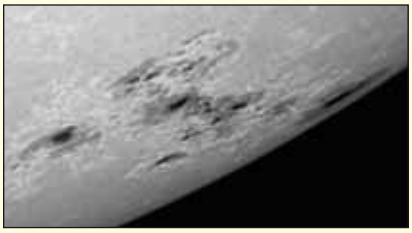
The bottom line is that you actually can obtain a decent setup — capable of high-quality webcam imaging — for as little as $500, and perhaps less. This represents tremendous value if you're just starting out in astrophotography. A

Damian A. Peach *is assistant director of the BAA Jupiter section, as well as the ALPO Jupiter section.*

The Sun allows big results with small filtered scopes

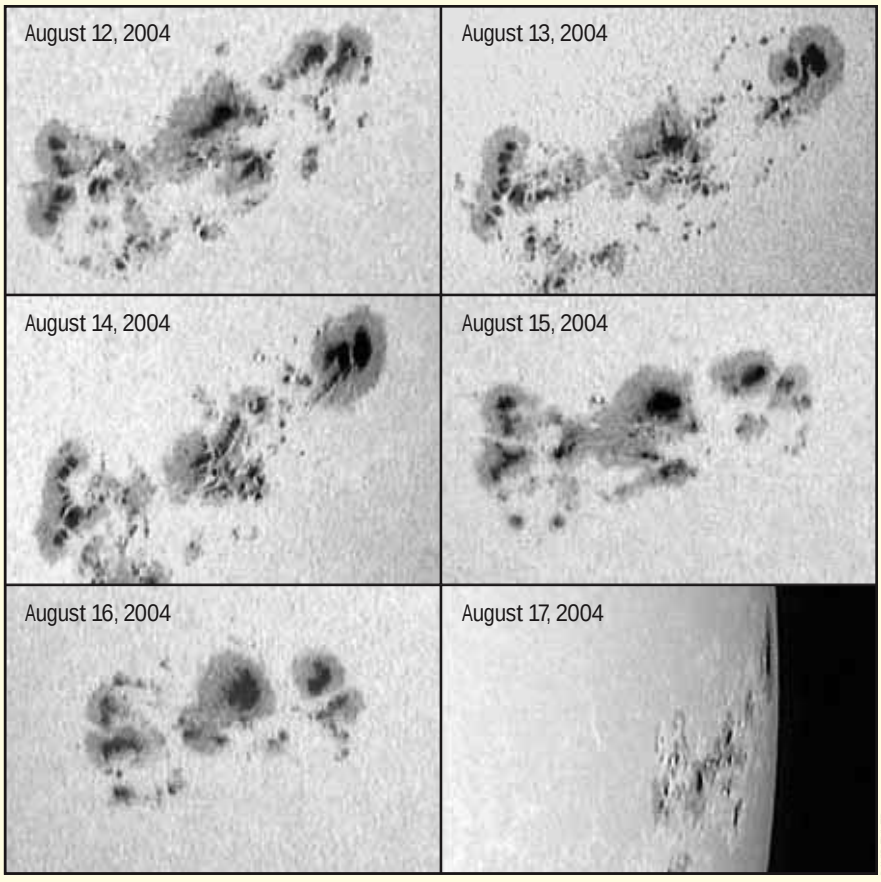
The Sun is a good target for 3- to 6-inch telescopes because larger telescopes are limited by turbulent daytime seeing conditions (in all but the best locations). Also, if you image in visible light, filters are not expensive. I use Baader AstroSolar Safety Film filter on my 3.2-inch Vixen refractor to good effect for both high-magnification and full-disk solar imaging.

Sunspot groups often show much fine detail in visible light, with changes to the spots occurring over the course of a few hours. When spots are located close to the Sun's edge, clouds of bright faculae often surround them — this can make for an especially nice image. Only short exposures are necessary — typically less than 1/250 second.



DAMIAN PEACH

GIANT SUNSPOT GROUP AR 0649 disappears over the solar limb in this image obtained by the author August 17, 2004. The author used a 3.2-inch apochromatic refractor, webcam, and Baader AstroSolar filter to create this image.



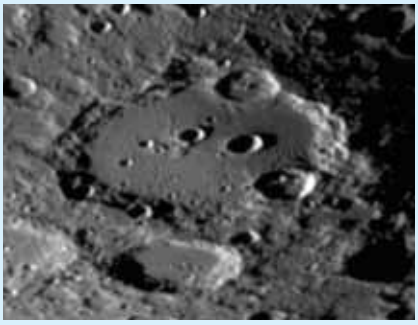
DAVID TYLER

A LARGE SUNSPOT GROUP develops over several days. All images were taken with a webcam attached to a 6-inch Maksutov-Cassegrain reflector.

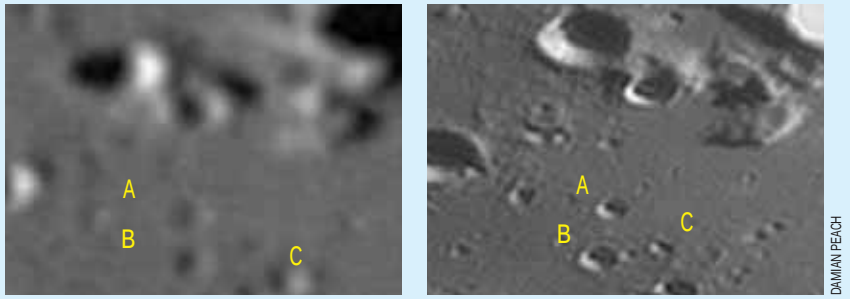
The Moon — ideal target for new astroimagers

The Moon is the obvious target for small-scope users. Lots of detail — much more than on the Sun — can be seen on its surface, and no filter is needed. You can achieve remarkable results using a 3- to 6-inch telescope. Captured by a webcam, your images will exceed in resolution the best Earth-based amateur photographs of 20 years ago no matter the scope's size.

A quality scope puts the small craterlets of Clavius or the famous Hadley rille within reach. One advantage of using small apertures for imaging the Moon is you can fit large areas of the lunar surface in the wider field of view. In addition, you can take spectacular montages of the lunar disk with relative ease.



THIS IMAGE OF CLAVIUS shows details as small as 0.9" — well below the theoretical resolution of the telescope used. The author created this image by attaching a webcam to a 3.2-inch apochromatic refractor.

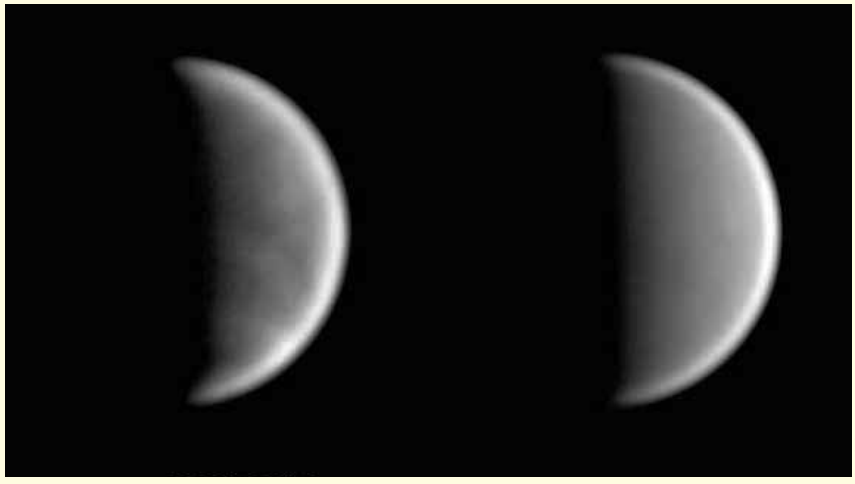


DAMIAN PEACH

A COMPARISON using small craters around Clavius shows large telescopes still have an advantage, but small scopes also show a lot of detail. With the same webcam on the same night, the left image was taken through a 3.2-inch refractor, and the right image was made through an 11-inch Newtonian reflector. Crater C spans only 1".

BEYOND THE SUN AND MOON

The planets are perhaps the most fascinating targets for small telescopes — and the most challenging. It's possible for a 3-inch telescope to produce scientifically valuable images of the planets, and a 6-inch aperture can produce images of remarkable quality. Whereas with film, only telescopes in the 10-inch and greater aperture range — under very steady seeing conditions — would produce decent results, today, the webcam has revolutionized what is possible.



CHRISTOPHE PELLIER

VENUS looks different through ultraviolet (left) and infrared filters. Note the dusky cloud markings visible in the ultraviolet image. These images were obtained August 15, 2004, through a black-and-white webcam attached to a 7.2-inch Newtonian reflector.

Capture dark markings on Mercury and Venus

The two inner planets make good targets for webcam-equipped small apertures — especially Venus, because it's bigger. The phases of both planets can be captured easily through a 3-inch scope, and interesting areas of study are accessible with a 6-inch.

Capture Mercury's dark surface markings using a deep red or infrared filter.

Venus presents a fascinating target for a 6-inch scope equipped with a webcam that has good blue sensitivity. While Venus' disk appears featureless in visible light, through an ultraviolet filter, you can follow its cloud markings easily.

DOMINIQUE DERRICK

THESE IMAGES OF MARS show dark markings and the south polar cap. The images were made August 28, 2003, through a webcam attached to a 3.2-inch apochromatic refractor.

Follow changes on Mars

Mars within a few months either side of its opposition date is a great target for a small scope with a webcam; a 3-inch apochromat can produce good images of the martian surface. Use a red filter to follow dust activity on the planet. Use blue filters to monitor polar-cap size and the amounts of clouds and haze in the atmosphere. You can obtain detailed images of the surface and atmosphere with a webcam and a 6-inch scope, even when Mars is as small as 10" in apparent diameter.

DAMIAN PEACH

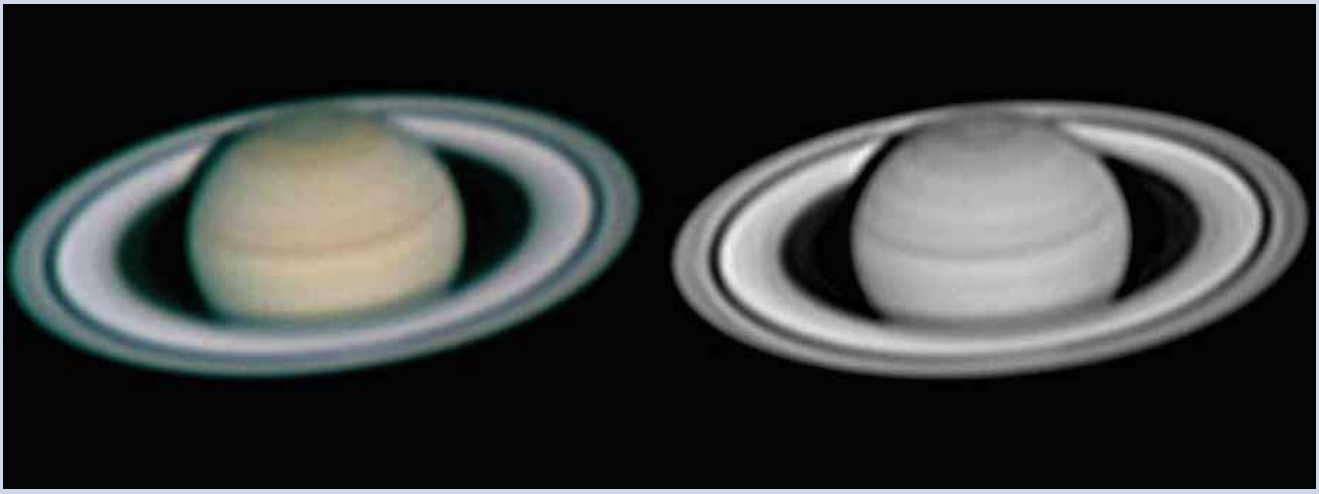
JUPITER is a popular target for amateur astronomers. The author took these images June 5, 2004, through a webcam attached to a 6-inch Maksutov-Newtonian reflector. Despite Jupiter's 25° altitude, the images reveal a wealth of fine detail across the jovian disk.

Giant Jupiter is perfect for small scopes

The giant planet is perhaps the most fascinating for study through any size telescope. Jupiter presents a constant maze of storm activity across its cloud tops that even small telescopes capture with ease.

You can make a wide range of Jupiter observations using a 6-inch telescope equipped with a webcam and a set of color filters. Even without the use of filters, highly detailed color imagery of the planet is possible through such an aperture. But before I go into more detail, what about users of telescopes in the 3- to 4-inch range? The famous blue festoons and the Great Red Spot are within this aperture range, and many storms and other features can be tracked, too.

With a 6-inch telescope, detailed images also are possible through both infrared and ultraviolet filters.



CHRISTOPHE PELLIER

TWO SATURN IMAGES, taken September 13 (left) and 17, 2003, through a webcam attached to a 7.2-inch Newtonian reflector, reveal many faint belts and zones. The image set from September 17 resulted in the discovery of a new bright spot on Saturn (not visible here).

Capture Saturn's details easily with a webcam

Because it has a lower surface brightness, Saturn is a more challenging target than Jupiter. While small apertures will produce nice images of the planet and rings (revealing the Cassini Division and the major belts), they don't collect enough light to study the saturnian atmosphere in detail.

The good news is that 6-inch telescopes are capable of producing excellent images of Saturn. A webcam image will reveal details in the atmosphere (such as small storms) and in the ring system. Also, as with Jupiter, you can use a wide range of filters for various effects.

DAMIAN PEACH

DOUBLE STARS usually are difficult objects to image because of the unsteadiness of Earth's atmosphere. The author used a 3.2-inch apochromatic refractor and a webcam to capture the two components of Epsilon (ε) Boötis.

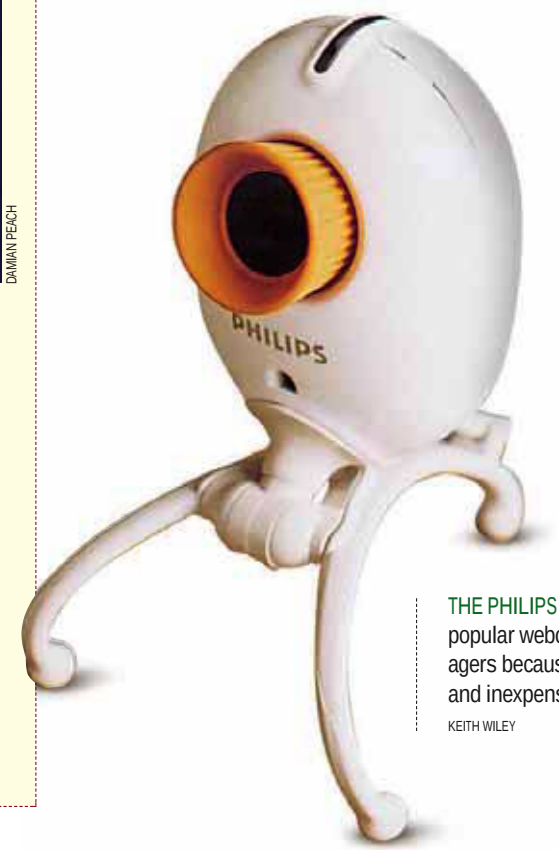
Try your skills on double stars

You might be surprised to learn your webcam/small scope combination can capture many double and multiple stars easily. For best results, image bright doubles whose components are similar in brightness; say a difference of no more than 2 magnitudes. Pick nights with good seeing, and choose only the best frames to combine into your final image.

With a webcam, it's possible to produce double-star images accurate enough that you can measure both the separation of the two stars and their position angle, relative to north.

Traveling in space

Now that you can get to the far reaches of the solar system for little money, there's no reason not to dazzle your friends with interplanetary imaging. And guess what: You don't have to tell them how easy it was.



THE PHILIPS TOUCAM PRO is a popular webcam among astroimagers because it's easy to use and inexpensive (under $100).

KEITH WILEY

PROFILE

Throughout his legendary career, British amateur astronomer Sir Patrick Moore has inspired generations of people to look up. /// BY WILLIAM SHEEHAN

The sky's knight

Author of more than 60 books, and

the longest-serving television presenter in history on the monthly BBC series *The Sky at Night*, British amateur astronomer Sir Patrick Moore, 82, was knighted in 2001 for "his services to the popularization of science and to broadcasting." His tenure as program host spans nearly 5 decades.

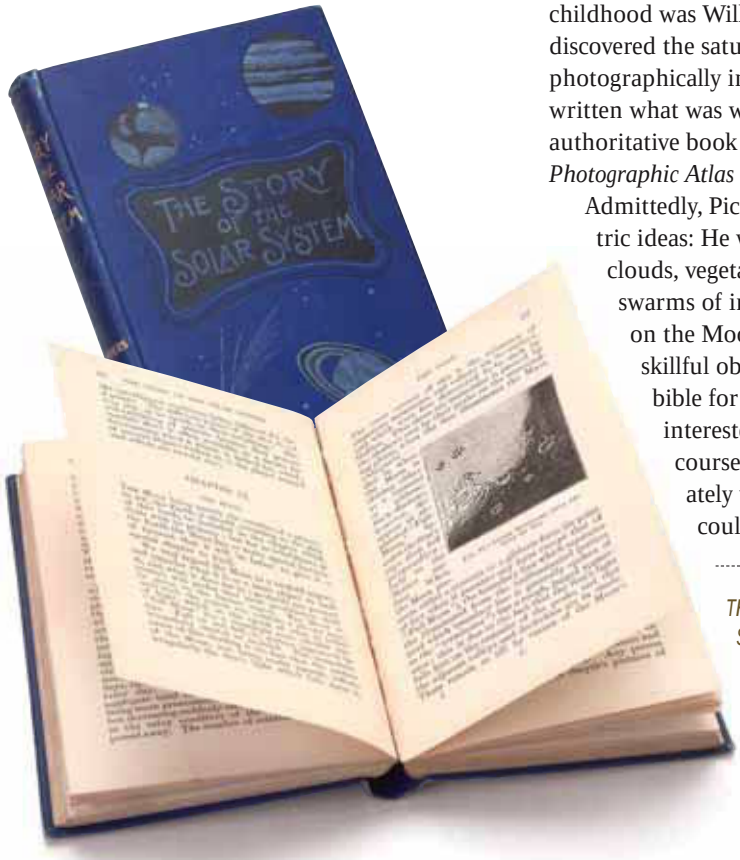
During that time, he has introduced generations of viewers to the wonders of the universe and inspired many to pursue astronomy as a career.

His own legendary career in astronomy can be traced back to a rainy morning in 1929, when he was 6 years old. His mother handed him George F. Chambers' pocket-size *The Story of the Solar System* (1895). He devoured it that day. Just 8 years later, Moore had his first set of keys to an observatory. By the time he was 30, he had written some of the most popular astronomy books in history and soon would begin his tenure as host of the British Broadcasting Corporation's *The Sky at Night*.

Lunar fascination

The Moon has always held Moore's interest. One of the notable figures during his childhood was William Pickering — who discovered the saturnian moon Phoebe photographically in 1898. Pickering had written what was widely considered the authoritative book on the Moon, *A Photographic Atlas of the Moon* (1903).

Admittedly, Pickering had some eccentric ideas: He was convinced vapor clouds, vegetation patches, even swarms of insects could be spotted on the Moon. But he was also a skillful observer. His book was a bible for amateur astronomers interested in our satellite. Of course, young Patrick desperately wanted the book, but he couldn't afford it.



THE STORY OF THE SOLAR SYSTEM by G. F. Chambers ignited Sir Patrick Moore's lifelong fascination with the night sky. Moore read this book when he was just 6 years old.

ASTRONOMY: WILLIAM ZUBACK

Eventually, he borrowed a copy and — having taught himself to type with two fingers — produced his own copy. It still exists in his library. He also copied other Moon-related books in this fashion.

By the early 1930s, Moore was making and recording his own observations. In 1934, for example, he observed his first Mars opposition. When he was 11, Moore became a member of the British Astronomical Association (BAA) to continue developing his interest in astronomy. At 14, when he was living in East Grinstead, Sussex, he became acquainted with one of the leading figures in the BAA, W. S. Franks, who ran the nearby Brockhurst Observatory. Franks recognized an enthusiast when he saw one, and promptly turned over the keys to Moore.

/// BEHIND THE MONOCLE

BBC PHOTO ARCHIVE

The monocle is part of Sir Patrick Moore's persona — he has worn it since he was 16. He sees no point in wearing glasses, because only one of his eyes is bad. Despite the monocle — without which he says he feels naked — Moore could not be more different than the stereotypical monocle-wearing figure. He is warm, chatty, and amiable. — *W. S.*

BBC PHOTO ARCHIVE

THE SKY AT NIGHT will celebrate its 50th anniversary in 2007. While the set, topics, and guests have changed during the show's record-setting longevity, the one constant has been Sir Patrick Moore's influence. The legendary amateur astronomer has inspired generations to appreciate the night sky.

World War II intervenes

World War II interrupted the progress of his academic career. Had Moore gone to Cambridge University instead of joining the Royal Air Force, he would have studied geology, not astronomy — his interest was planetary science. As a navigator in the RAF bomber command, Moore sometimes would observe the Moon with a homemade reflector. After being shot down by the Germans, doctors told Moore his body wouldn't last to the age of 30. He proved them wrong — he continued to play cricket as a member of the Selsey Cricket Club until age 77.

After the war, Moore returned to East Grinstead and devoted himself to writing. He knew he could succeed as a freelancer, and he was amazingly prolific — book followed book in rapid succession. His easy-to-understand prose and colloquial tone helped them become classics. He translated the French astronomer Gerard de Vaucouleurs' *Physics of the Planet Mars* (1953). His own breakthrough was *Guide to the Moon* (1953). It has now gone into

/// BACKYARD SCIENTIST

Moore devised many simple experiments involving limited equipment. For instance, in the pre-Mariner 4 days, he studied the ability of a cactus to survive a night in a Mars-like environment (it didn't do well).

Moore also tested the claim that it is possible to see the crescent phase of Venus with the naked eye by mischievously showing a telescopic view of the planet on TV when he was soliciting those observations. Of course, the horns of the planet were reversed in the telescopic image, and out of a multitude of observations, only four were "right-side-up" and thus possibly genuine. — *W. S.*

COURTESY OF ARMAGH PLANETARIUM

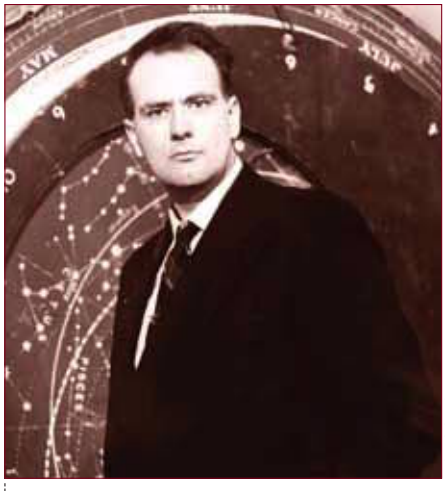
AS FOUNDING DIRECTOR of Armagh Planetarium in Northern Ireland, Moore — seen here in 1967 next to the planetarium's telescope — became frustrated with the region's religious tension.

COURTESY OF ARMAGH PLANETARIUM

MOORE STAYED at the Armagh Planetarium for less than 2 years before returning to Sussex.

eight editions — the latest having been renamed *Patrick Moore on the Moon*. As Moore points out, the title is misleading because he has never been to the Moon: "It would take a very massive rocket to launch me into space." In 1955, he produced *Guide to the Planets*, *The Moon* (with H. P. Wilkins), and *Making and Using a Telescope* (also with Wilkins).

He collaborated a great deal in those days with Wilkins, who had plenty of time to pursue astronomy as a civil servant, Moore quips. Wilkins was the director of the BAA Lunar Section and completing work on a 300-inch lunar map — the largest produced by a visual observer.



BBC PHOTO ARCHIVE

NOT EVEN THE YOUNG, enthusiastic Patrick Moore could've guessed 48 years ago his BBC program, *The Sky at Night*, would become one of the longest-running TV series.

Wilkins and Moore made regular forays to Meudon Observatory, just outside Paris, to scrutinize the Moon with the "Grand Lunette" — the 33-inch refractor that had been in use since the late 19th century.

Their reports were awaited by lunar observers like news from the war front. The volcanic theory of lunar crater origin was still *en vogue*, and Moore — like most British observers of the Moon — always believed volcanism was the most reasonable explanation for lunar craters. He remained ever on the lookout for minor changes in the lunar surface, perhaps produced by gaseous emissions, and later coined the term "Transient Lunar Phenomena" (TLP). Confidence in the reality of TLPs, however, has declined since the Apollo missions.

A celebrity is born

Sputnik I launched October 4, 1957 — remarkably lucky timing. Moore had just started to broadcast the BBC series *The Sky at Night*. It would become the BBC's longest-running science series. In fact, for 47 years, Moore never missed a broadcast. The streak was broken last summer, when he was hospitalized with salmonella after eating a spoiled duck egg.

As the "space race" became the "Moon race," Moore participated in ground-based Moon mapping for the U.S. Air Force using Lowell Observatory's 24-inch reflector.

In 1968, after a brief stint as director of the Armagh Planetarium in Northern Ireland, Moore moved back to England, acquired a dilapidated building in Selsey Bill, Sussex, where he settled with his mother. He bought the house with almost the last farthing he had.

In 1969, Moore solidified his fortune with *Atlas of the Moon*, which sold 800,000 copies — a publishing success allowing him to renovate his house in a grand style. Amateur astronomers from around the world have come to visit him there and use his telescopes ever since.

/// THE FARSIDE OF THE MOON

On October 26, 1959, Moore was presenting a live broadcast of *The Sky at Night* when the first pictures of the Moon's farside came back. He recalls: "In my ear, I heard the producer's voice: 'Pictures coming through in 1 minute. Scrap all your plans — do it off the cuff. Good luck!' I said to the audience, 'Well, the pictures are coming up now.' And up on the screen came the pictures of the Moon's farside — mountainous, cratered, ridges, valleys. No little green men, but it was a great moment."— *Matthew Quandt*

Meeting Moore

I first visited Moore September 23, 1993. He met me dressed in an untucked red-and-white plaid shirt. We drove in his

William Sheehan *is a psychiatrist, science historian, and noted speaker. His most recent book is* The Transits of Venus *(Prometheus Books, 2004).*

1940s' Ford, the "Ark," to Farthings. We then retreated to his study — insulated by the mementos of a full life — where we relaxed and had a drink.

We looked over his telescopes and his meteorological station in the backyard. That night, we walked to an Indian restaurant nearby. The low-hanging, orange gibbous autumn Moon just cleared the wall by his splendid old house as we returned from dinner. Watching it, Moore told me how, in the 1940s, he had discovered and named Mare Orientale.

I did not see him again until May 2004 — just before the June 8 transit of Venus. I first read about this historic event in Moore's *The Story of Astronomy* — lavishly illustrated and eloquently presented — 40 years earlier.

Unfortunately, his vertebral column has given way, and he walks with the help of two canes now. He lost the grip and agility of his hands and has given up cricket and playing the xylophone.

A talented musician, Moore was heartbroken that he was unable to compose a transit of Venus march. He did, however, succeed in observing it from his backyard along with a BBC camera team.

"The beyond"

Moore has been honored with many awards, besides his 2001 knighthood. For example, in 1978, he received the Astronomical Society of the Pacific's prestigious Klumpke-Roberts Award, which recognizes outstanding contributions to public understanding and appreciation of astronomy.

Unable to operate his telescopes, he has given them away to friends — like professional planetary astronomer and author Peter Cattermole, whom Moore had encouraged when Cattermole was a schoolboy in East Grinstead.

Moore writes as often as he can. He no longer types 90 words a minute, but uses the same 1908 Woodstock typewriter he has owned for decades.

When the time comes for him to go, he has planned an experiment. His survivors will light a candle so, if he can, he will blow it out from "the beyond," wherever that is. Moore is a man of his word, and if it can be done, he will do it. A

Astronomy editors discuss their favorite Moore books at *www.astronomy.com/toc*

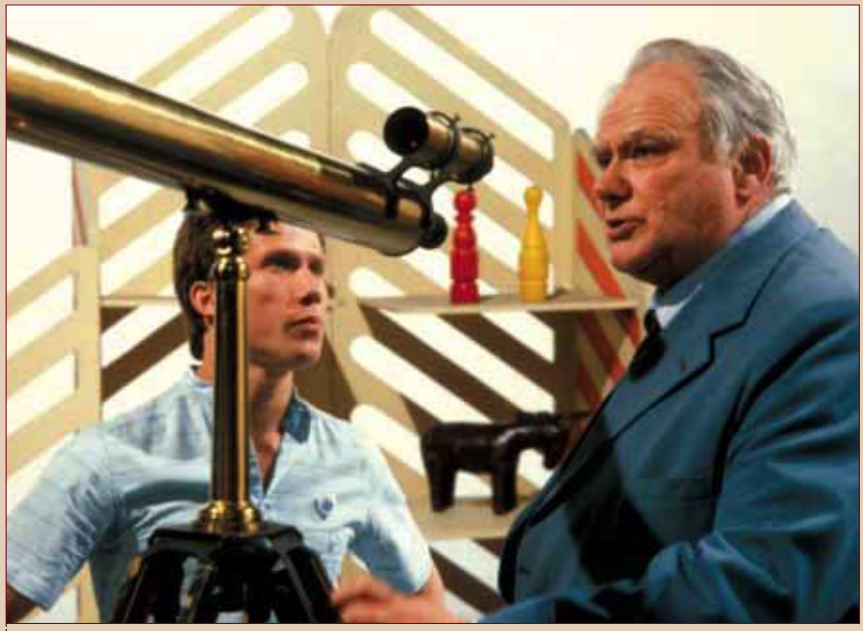
/// SIR PATRICK MOORE – A BROADCASTING LEGEND

Martin Rees, Astronomer Royal of England and professor of cosmology and astrophysics at the University of Cambridge, gives his account of Moore's legacy:

"I actually first recall seeing and hearing Patrick when I was a schoolboy in 1957. He was broadcasting from [the University of Manchester's] Jodrell Bank [Observatory] about the first Sputnik. I had the pleasure of recalling this — and expressing my immense admiration for Patrick — when I appeared on the 600th episode of *The Sky at Night*, which was recorded at his home about 2 years ago.

"Patrick describes himself as an 'amateur,' but he's immensely well-informed. As a communicator, he is a consummate professional. He can stand up and talk in front of a camera without hesitation, deviation, or repetition, for exactly the allotted time, even about the latest discoveries that none of us has yet had time to digest.

"As well as his broadcasting and writing, he's always been immensely helpful to amateur groups and to individual astronomers, young and old."



BBC PHOTO ARCHIVE

BLENDING WIT WITH WISDOM, Moore passes his passion for astronomy to his show's guests and viewers alike. In this image from 1982, Moore talks with a guest, Peter Duncan, near an antique refractor on the program's set.

JOHN FLETCHER

FRIENDS AND MEDIA gathered with Moore in the backyard of his home in Selsey Bill, Sussex, to watch the historic transit of Venus June 8, 2004. All eyes are on the iconic Moore as he describes the transit's significance for his BBC series, *The Sky at Night*.

This large scope offers high-quality optics in a lightweight package. /// BY ANTHONY E. NELSON

The big easy

Spring nights beckon observers.

As amateur astronomers whose dreams usually outstrip our budgets, my little stargazer group usually focuses on somehow obtaining new scopes with big mirrors. In our dreams, of course, we don't have to carry these large, cumbersome scopes or set them up at a site. Dream-scopes have an advantage over the real thing: They can never contribute to a hernia.

THE 12½-INCH F/4.8 PRIMARY MIRROR is the major component of the StarStructure Newtonian telescope. Once you install it in the mirror box, you can leave it there permanently.

StarStructure basics

I enjoyed being the focus of my friends' envy when I had the opportunity to field-test StarStructure Telescopes' 12½-inch f/4.8 Dobsonian-mounted, truss-tube reflecting telescope. Priced at $3,295, the basic model comes with a custom-fit light shroud, a JMI DX-3 focuser, and a Rigel QuikFinder. The telescope arrived in a sturdy wooden crate packed with fitted Styrofoam that prevented jostling during shipping. The telescope came in eight pieces, the smallest of which were the four trusses. Bolts and other small parts were packed together in a box.

The StarStructure scope is surprisingly light — far lighter than typical Dobsonian-mounted ones of equal aperture. It is made entirely of aluminum, except, of course, the optics. Completely assembled, this 12½-inch telescope weighs a meager 76 pounds. The heaviest component is the mirror box with the mirror installed, and it is an easily manageable 45 pounds.

The StarStructure 12½-inch is light enough that almost anyone can assemble it. An enclosed-tube Dobsonian telescope with a similar-size mirror is typically about 20 pounds heavier, with the heaviest component weighing about 55 pounds.

Aluminum construction also helps decrease the time needed for the mirror to cool to ambient temperature compared with traditional truss-tube designs. The overall fabrication is of high quality, and the light, easy-to-manage components fit into the trunk of my small sedan; the mirror box rides in the back seat.

THE MIRROR BOX (sometimes called the rocker box) houses the telescope's 12½-inch primary mirror. With the mirror installed, the mirror box weighs only 45 pounds, making it easy to manage during setup.

The StarStructure is a real eye-catcher. Its blue and black-and-white paint scheme stands out in a crowd. With the light-shroud off, the scope reveals high-tech architecture. Metal lines and angles meld science and art into a beautiful and useful scientific tool. I received many compliments from people at star parties and public observing sessions on the StarStructure's visual appeal.

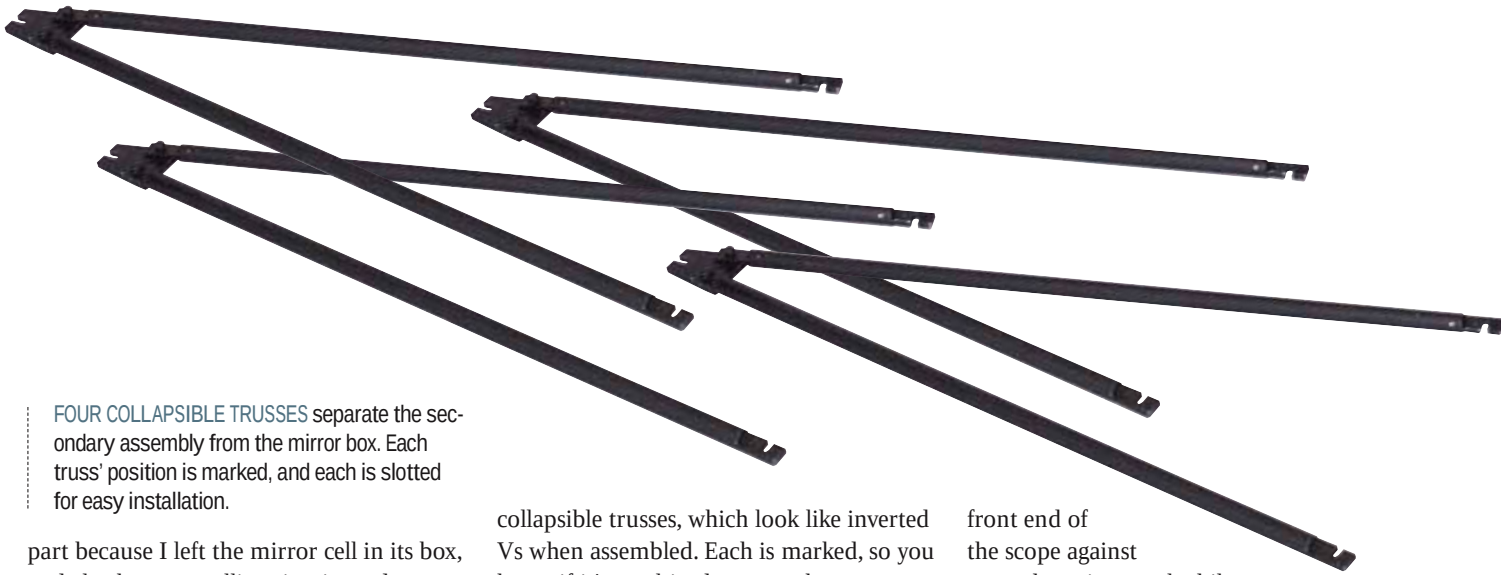
Snappy setup

Following the written instructions to the letter, I completed initial setup of the telescope in less than 15 minutes. Collimation took less than 5 minutes, so I was ready to observe — delayed only by the Sun — in about 20 minutes.

Every setup after the first took less than 15 minutes — including collimation — in

ASTRONOMY: JAMES FORBES PHOTOS

STARSTRUCTURE TELESCOPES' 12½-INCH Dobsonian-mounted reflector is lightweight for its size.



FOUR COLLAPSIBLE TRUSSES separate the secondary assembly from the mirror box. Each truss' position is marked, and each is slotted for easy installation.

part because I left the mirror cell in its box, and also because collimation is made easy by the scope's design. The three collimation knobs are large and easy to manipulate, even in the dark wearing thick gloves.

Part of what makes this scope so easy to set up is the truss system: four one-piece, collapsible trusses, which look like inverted Vs when assembled. Each is marked, so you know if it's an altitude, top, or bottom truss. Each truss bottom is slotted on its inner side to mate to a pair of wing nuts on the mirror box. The top of each truss also is slotted to receive one of the wing nuts on the front end.

The mirror cell has two posts, which mate to holes in the mirror box, so you can insert the mirror cell correctly every time. Because of the telescope's near-perfect balance, it's a good idea to lean the front end of the scope against your observing stool while you set the mirror cell in the mirror box. This ensures the scope will not move when you put the rear bolts into place.

Because of the mirror's size, I expected the telescope's cool-down period to last an hour longer than it did. When the mirror stabilized, I was able to do what I had wanted to do since the box first arrived at my house: observe.

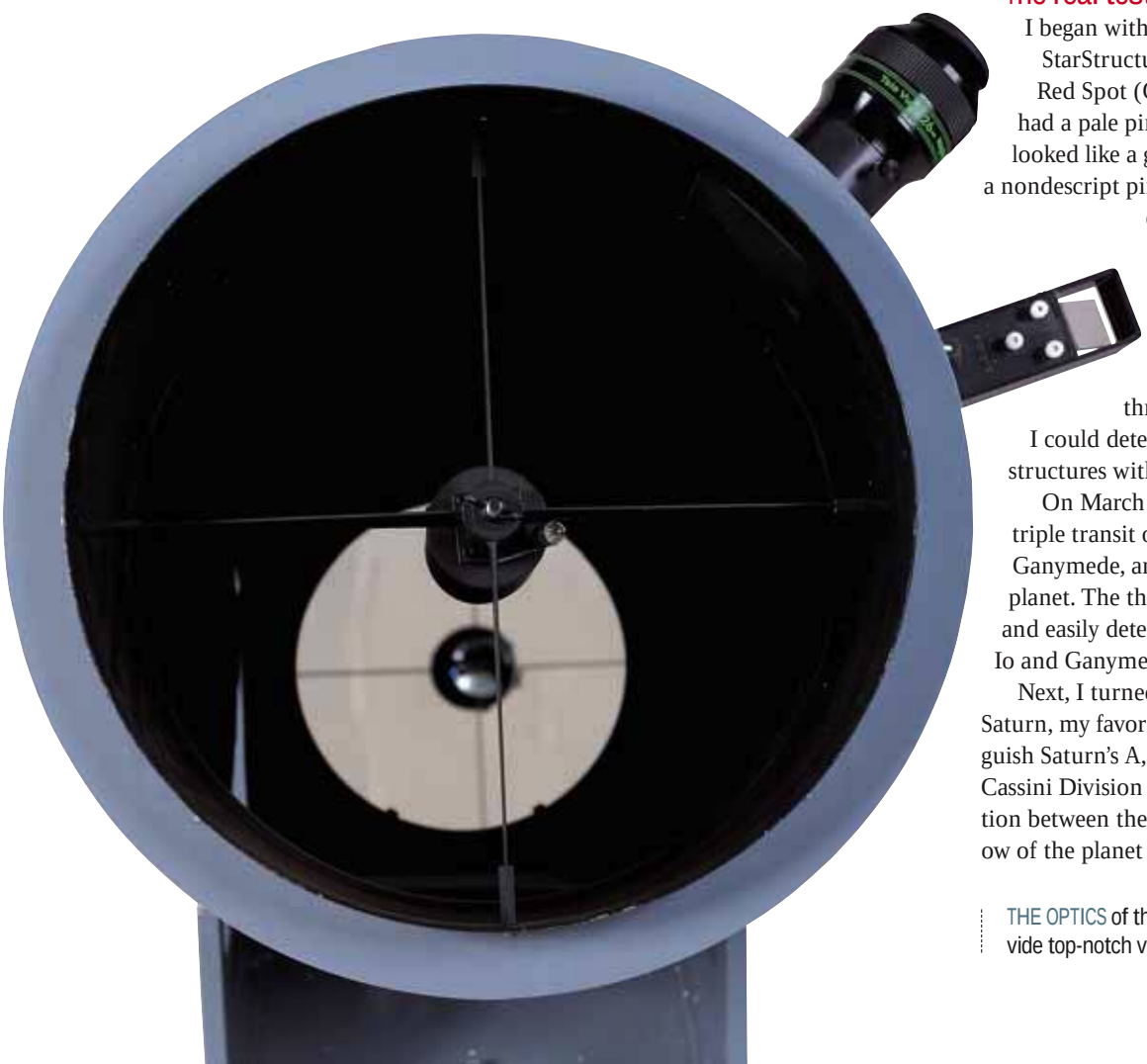
Anthony E. Nelson *observes under the clear sky of West Texas and is the managing editor of* Synthese: An International Journal for Epistemology, Methodology, and Philosophy of Science.

The real test — the sky

I began with Jupiter. Through the StarStructure 12½-inch, the Great Red Spot (GRS) was well defined and had a pale pink color. The GRS actually looked like a giant hurricane instead of a nondescript pinkish oval. Jupiter's northern and southern equatorial bands usually look like muddy stripes when viewed through the smaller scopes I typically use, but through the StarStructure, I could detect small formations and structures within the bands.

On March 27, 2004, I observed the triple transit of the shadows of Io, Ganymede, and Callisto across the giant planet. The three shadows were sharp and easily detected, as were the disks of Io and Ganymede.

Next, I turned the StarStructure toward Saturn, my favorite planet. I could distinguish Saturn's A, B, and C rings clearly. The Cassini Division was a sharp, dark separation between the A and B rings. The shadow of the planet across the rings was sharp.



THE OPTICS of the StarStructure 12½-inch provide top-notch views of celestial objects.

THE SECONDARY ASSEMBLY (sometimes called the cage) contains the secondary mirror and its four support vanes. The focuser and any finder scope also attach to the cage.

I lingered on Saturn for quite a while before changing targets.

One of my fellow astronomers not stricken with envy let me borrow his hydrogen-beta filter, and I was on the hunt for the Horsehead Nebula (B33) in Orion. Because B33 is one of my favorite objects, I've viewed it through a number of amateur scopes. The StarStructure's view was superior to most and equal to the best.

The Orion Nebula (M42) was spectacular through this telescope. The wispy nebulosity was clear and had depth to it. Using a 7mm eyepiece, which provided a magnification of 218x, I was able to pick out the E and F stars in the Trapezium clearly.

The face-on spiral galaxy M101 in Ursa Major revealed fine spiral arms with clear divisions between them. Using this scope, it seemed that nothing looked like a nondescript, fuzzy blob. The great globular cluster M13 in Hercules, for instance, was a tight group of pinpricks instead of a bright, indistinct patch of light.

What I really think

The StarStructure 12½-inch has many advantages, but the biggest is its weight. My wife, who is small of frame, had absolutely no problem setting up the telescope alone. She has never been able to set up a solid-tube Dobsonian of equal aperture because of the tube's weight and awkwardness.

Lastly, this scope is durable. When several teachers invited me to bring the StarStructure 12½-inch to an observing session for an elementary school, I knew the students couldn't damage the scope because it's fabricated from aircraft-grade aluminum.

I found the StarStructure to be a well-designed, versatile, and easy-to-operate telescope. However, I did encounter two minor difficulties. The Rigel QuikFinder single-power finder was adequate, but not the model or design I would have chosen to pair with such a high-end product. Many people like the QuikFinder, but I prefer either the Telrad finder, which is packaged with other scopes manufactured by StarStructure, or a 9x50 finder scope. The telescope seemed a little bottom heavy, but when I installed a borrowed Telrad, the balance problem no longer existed.

My second difficulty was not a telescope flaw but the wind. The scope's lightweight construction is, as I've stated, a benefit. But during a West Texas spring, it can become a problem when observing in the open. Exposed to winds of 20 to 25 mph, the scope had a tendency to become a weather vane. Once, when facing into the wind, the tube lifted up during a sudden gust, causing the eyepiece to poke me in the eye. This was a test, however. I'd never observe during high winds.

So, if you're looking for that perfect — but elusive — combination of large aperture and portability, the StarStructure 12½-inch may be your best choice.

/// PRODUCT SPECIFICATIONS

STARSTRUCTURE 12½-INCH
- 12½-inch Newtonian reflector
- 1,524mm focal length at f/4.8
- JMI DX-3 focuser included
- Rigel QuikFinder included

Dimensions/weight:
60 inches (at zenith)/76 pounds

Retail Price:
$3,295

Contact information:
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[w] www.starstructuretelescopes.com

THE BASE of any Dobsonian reflector must be stable or else observing will be difficult (if not impossible). The StarStructure Telescopes' foundation is sturdy and of high quality.

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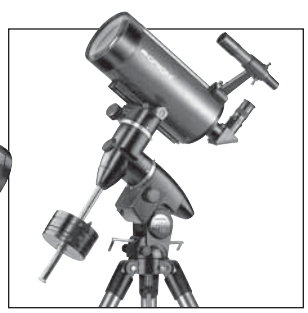
SkyView Pro 8 EQ

A full 8" (203mm, f/4.9) parabolic primary mirror, which gathers 73% more light than a 6". The tube features a 2" aluminum rack-and-pinion focuser and a sturdy 4-vane holder. Includes 6x30 finder scope, two 1.25" Sirius Plössl eyepieces (25mm and 10mm), collimation cap and dust-cap.

SVP 8 & FREE drive **$549**



SkyView Pro 127 EQ

The 5" Maksutov-Cassegrain optics offer great views of deep-sky gems. And its long focal length of 1540mm (f/12.1) is great for high-magnification study of the Moon and planets. Includes 6x30 finder scope, two 1.25" Sirius Plössl eyepieces, 90° mirror star diagonal, optical tube carry case and dust-cap.

SVP 127 EQ & FREE drive **$649**

New! & Notable

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Get smooth, precise focusing without vibration with the AccuFocus electronic focuser. Includes bracket, hardware, and coil cable. See telescope.com for compatible telescopes. **$49.95**

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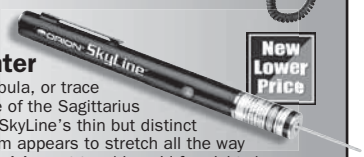

New Lower Price

Point right to the Orion Nebula, or trace the outline of the Sagittarius "Teapot." SkyLine's thin but distinct green beam appears to stretch all the way to the stars! A great teaching aid for night-sky viewers. Two AAA batteries and case included.

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Take awesome through-the-eyepiece shots of planets, the Moon, or terrestrial subjects with your digital or film camera. SteadyPix couples camera to most 1.25" telescope eyepieces.

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Deluxe Stargazer's Filter Set

For the observing enthusiast, this six-filter collection is all you need. Includes SkyGlow, variable polarizing filter, and four color planetary filters (1.25") in one carry-all case.

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For precise collimation of your reflector's optics. The LaserMate Deluxe turns collimation into a one-step process by adding a "rear view" port so you can see both the emitted and return beams while standing at the rear of the telescope. Both fit any 1.25" eyepiece holder.

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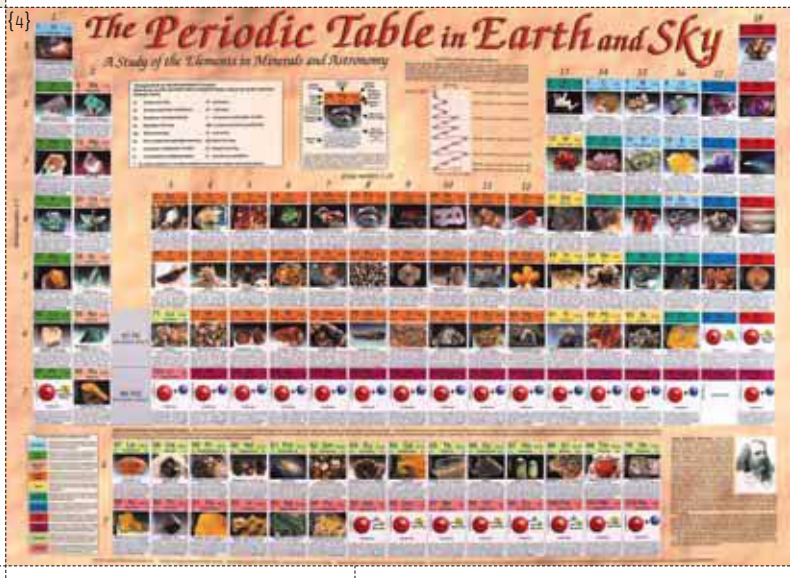

1. Hazel Stevens framed tiles

Hazel Stevens Designs has produced a new series of framed ceramic tiles. These 8" by 8" frames, which include a tile of your choice, are available in natural blonde or rosewood-stained alderwood. A drilled keyhole on the reverse side allows you to hang the tile. Framed tiles can also be used as hot plates or trivets. Four rubber feet on the back protect the surface.

$50–53; Hazel Stevens Designs
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2. MoonLite Dual Rate CF2-s focuser

MoonLite Telescope Accessories has produced a line of Crayford-style focusers to upgrade several models of refractors. The CF2-s is a direct replacement for the rack-and-pinion units found on Synta-brand refractors. The CF2-s is a dual-rate unit — fine focus is an 8-to-1 reduction of the regular focusing rate. The CF2-s also provides 4½ inches of travel, zero backlash, and no image shift.

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3. Nikon Lens Pen

Nikon's Lens Pen is a cleaning tool for high-quality optics. Use it to clean fingerprints, grease marks, smudges, and dust from telescope eyepieces, camera lenses, finder scopes, and binoculars without scratching or damaging them. Its tip is self-replenishing, and the cleaning compound will not spill out or dry up. It's also safe for all multicoated surfaces.

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4. Jensan Scientifics periodic table

Jensan Scientifics' Periodic Table in Earth and Sky graphically shows how astronomy and chemistry are related. The table features 117 razor-sharp photographs, information about each element as to its abundance in Earth's crust, cosmic abundance, element symbol, atomic weight, and important uses. The poster measures 38.5" by 27" and is laminated.

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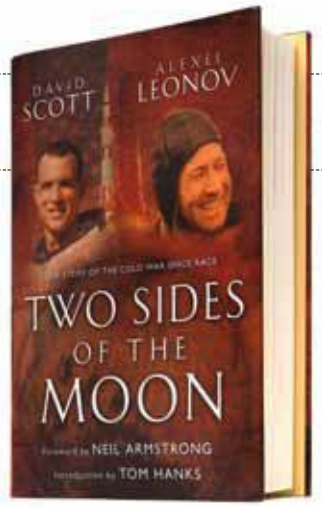

Both sides now: the Cold War Space Race

Two Sides of the Moon

David Scott and Alexei Leonov, 416 pages, St. Martin's Press, 2004; hardcover, $25.95

The day after Apollo 11 made the first lunar landing, I asked my father, "How did the Russian cosmonauts feel when Neil Armstrong walked on the Moon?" He said he had no idea, but figured they might be upset that we were first.

But until I read *Two Sides of the Moon*, I never knew what the cosmonauts really thought. Here's a quote from Cosmonaut Alexei Leonov:

"On the morning of 21 July 1969 everyone forgot, for a few moments, that we were all citizens of different countries on Earth ... Even in the military center where I stood, where military men were observing the achievements of our rival superpower, there was loud applause."

Two Sides is unique among space histories as it is told from two perspectives — that of David Scott, American astronaut and commander of the Apollo 15 mission to the Moon, and the other from Alexei Leonov, Soviet cosmonaut and the first man to walk in space. Their experiences and views, running side by side, help readers gain a real sense of the Race to the Moon and the triumphs and tragedies encountered by both countries along the way. Two better men could not have been chosen to tell the tale — both pilots, loyal to their countries, willing to take risks to ensure mission success. These two are the same and yet different.

The book starts as a dual biography, giving brief accounts of each man's childhood and military service. Then the Space Race begins, and we hear much from Leonov about the Soviet dominance in the early years. You sense his pride in the historic flight of his good friend, Yuri Gagarin, the first person to orbit Earth. I found myself riveted by Leonov's account of the first space walk, when his suit expanded too much to fit back in the airlock. Leonov decided on his own to bleed some air from the suit.

Beginning with the Gemini program, and especially during Apollo, Scott's story comes to the fore. I found illuminating his insights on the character of Neil Armstrong, his commander on Gemini 8. Scott's description of the hair-raising spin of the Gemini spacecraft during their mission made real for me how close they came to "buying the farm."

Scott's account of the Apollo 15 mission to the Hadley Rille at the foot of the lunar Apennines and the training leading up to it comes across almost like poetry. His descriptions of the Moon are vivid and detailed.

The book's last part shifts from competition to cooperation as both countries prepare for a joint space venture, the Apollo-Soyuz Test Project. Accounts of meetings between cosmonauts and astronauts nicely illustrate the cultural differences between the United States and the Soviet Union. Sometimes, it seems the two men could not possibly be describing the same event. Leonov gives a nice description of the mission, which was not without glitches. I had no idea, for example, that a mistaken firing of the Apollo thrusters could have damaged the Soyuz.

If you are looking for a balanced, interesting, and personal account of the American and Soviet space programs during the 1960s and '70s, this is it.

— BILL COOKE *lives in Huntsville, Alabama, where he improves spacecraft designs by modeling the meteoroid environment for NASA's Marshall Space Flight Center.*

The Story of the Space Shuttle

David M. Harland, 444 pages, Springer, 2004; paperback, $29.95

As the space shuttles near their return to flight, this book by a veteran space reporter gives a detailed history of the shuttle program. It concludes with chapters detailing the Columbia disaster and plans for spacecraft to replace the shuttle. A log summarizes the crews and payloads for each flight, including Columbia's last.

The Transit of Venus

Peter Aughton, 210 pages, Weidenfeld & Nicolson, 2005; hardcover, $35

This engaging book tells of the life of Jeremiah Horrocks (1618–1641). He was an English astronomer who was the first to observe a transit of Venus by telescope, in 1639, and to calculate the Sun's distance using it. Aughton calls Horrocks "the father of British astronomy" and argues he would be far better known today had life given him more than the bare few years he got.

The Living Universe

Steven J. Dick and James E. Strick, 308 pages, Rutgers University Press, 2004; hardcover, $49.95

While it seems NASA jumped into astrobiology fairly recently, as Dick and Strick relate it, the agency became interested in the subject, then known as exobiology, in the late 1950s. This history of astrobiology, both outside NASA and within, covers a lot of ground. It also provides a description of the ALH84001 case, in which possible martian fossils were found in a meteorite.

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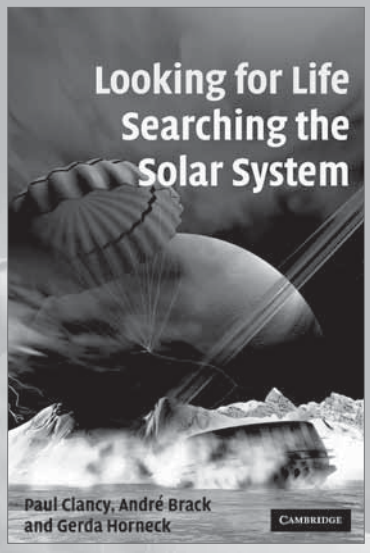
WHAT'S NEW IN ASTRONOMY?



Looking for Life, Searching the Solar System

Paul Clancy, André Brack, and Gerda Horneck

Is life confined to our planet? Will humans one day be able to travel long distances in space in search of other life forms? Written by three experts this chronicle of potentially amazing discoveries answers these and other intriguing questions. It explores the origins of life on Earth, what we know about it, and what we don't; the ability of life to survive in space and on the surfaces of planets; and how the spirit of discovery as exemplified by past explorers will drive the human race out into our solar system in the search for life on other planets. *Looking for Life, Searching the Solar System* is an invaluable contribution to the fast-growing and fascinating field of astro-exobiology by bringing all its key topics under one cover and by mapping out the future in this vital area of space exploration.

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STELLAR ARCHAEOLOGY

ARTICLES — In "M67: the ultimate survivor" (*Astronomy*, March 2004), astronomer Ken Croswell looked at an unusually old open star cluster — one that somehow has avoided disruption by nearby massive molecular clouds.

Andrew Layden and Ata Sarajedini speculated M54 is the former nucleus of the Sagittarius dwarf galaxy in the paper "Photometry of the Globular Cluster M54 and the Sagittarius Dwarf Galaxy: the Age-Metallicity Relation," published in the April 2000 issue of *The Astronomical Journal*.

WEB — A detailed summary of Richard de Grijs' work on young star clusters, as well as links to his recent papers on the subject, is available at *www.shef.ac.uk/physics/people/grijs/Research*.

William Harris, professor of physics and astronomy at McMaster University, maintains a detailed catalog of the Milky Way's 150 globular clusters at *physun.mcmaster.ca/~harris/mwgc.dat*.

SPACE BUZZ

BOOK — Buzz Aldrin provides an intimate account of the 1960s space race between the United States and Soviet Union in *Men from Earth* (Bantam, 1989). He provides great insight on his flights during both the Gemini and Apollo programs.

ARTICLE — To find out what it was like for Aldrin and the other Apollo astronauts who went to the Moon, see "The Moon voyagers" by Andrew Chaikin (*Astronomy*, July 1994). It was one of three articles in that issue commemorating the 25th anniversary of the first Moon landing.

VAGABOND MOONS

BOOK — Few of the giant planets' irregular satellites have much of a presence in books, but take a look at *Satellites of the Outer Planets* by David Rothery (Oxford University Press, 1999). The author concentrates on larger moons, most of whose surfaces show complex geological processes. But the book provides a detailed look at the environments where irregular satellites dwell, and the processes that affect them.

WEB — Visit Scott Sheppard's page, *www.ifa.hawaii.edu/~sheppard/satellites*, to stay on top of recent discoveries of outer-planet moons. The site also provides information on the moons, their membership in satellite families, and their orbits and physical nature.

A SPIRAL MASTERPIECE

BOOK — Find observing notes about M101 and several members of its group in *Observing Handbook and Catalogue of Deep-Sky Objects* by Christian Luginbuhl and Brian Skiff (Cambridge University Press, 1990). The duo used 2.4-, 6-, and 12-inch telescopes for their observations.

WEB — Find historical and observational information about M101, including links to papers and images, at the Students for the Exploration and Development of Space (SEDS) site: *www.seds.org/messier/m/m101.html*.

ASK ASTRO

ARTICLE — Figures for the Sun's future size and the survivability of various planets come from the paper "On the final destiny of the Earth and the solar system" by Kacper Rybicki and Carlo Denis, published in the May 2001 issue of *Icarus*.

WEB — The University of Arizona's Lunar and Planetary Laboratory developed a site for estimating the regional environmental consequences of an asteroid impact at *www.lpl.arizona.edu/impacteffects*. This program will estimate the size of the crater produced, as well as the distribution of ejecta, the extent of the atmospheric blast wave, and the impact's heat effects.

SAIL A HIDDEN SEA

BOOKS — A useful guidebook to exploring the Moon by telescope is *Discover the Moon* by Jean Lacroux and Christian Legrand (Cambridge University Press, 2004).

Charles Wood's *The Modern Moon* (Sky Publishing, 2004) provides geological detail of the lunar surface.

For observing, the best lunar atlas is Antonín Rükl's *Atlas of the Moon* (Sky Publishing, 2004).

No Moon-buff should miss Don Wilhelms' insider account of lunar science from the 1950s through the 1970s, *To a Rocky Moon: A Geologist's History of Lunar Exploration* (University of Arizona Press, 1993).

WEB — The Lunar and Planetary Institute offers digital lunar atlases (photographic and cartographic) at *www.lpi.usra.edu/research/lunar_atlases*.

The most thorough account of lunar geology is Don Wilhelms' *The Geologic History of the Moon* (U.S. Geological Survey, 1987). It is long out of print, but an on-line version is available (as downloadable PDF files) at *cps.earth.northwestern.edu/ghm*.

SMALL EYES ON THE SKY

BOOK — Find a detailed, general, non-astronomical introduction to webcams in *Guide to Webcams* by John Breeden and Jason Byrne (Prompt Publishing, 2000).

WEB — The Astronomy Webcams Paradise, located at *sweiller.free.fr*, contains movies as well as still images. Some of the text is in French, but much of the information is in English.

The QuickCam and Unconventional Imaging Astronomy Group (QCUIAG) is at *www.qcuiag.co.uk*. This site contains a wealth of information about webcam modification, long-exposure astrophotography, and many more related topics.

THE SKY'S KNIGHT

WEB — *The Sky at Night* site, *www.bbc.co.uk/science/space/spaceguide/skyatnight*, is perhaps the most comprehensive source on Sir Patrick Moore. It offers a history of *The Sky at Night*, an interview with Moore about astronomy and his career, previous episodes for on-line viewing, and a multimedia tribute to the show.

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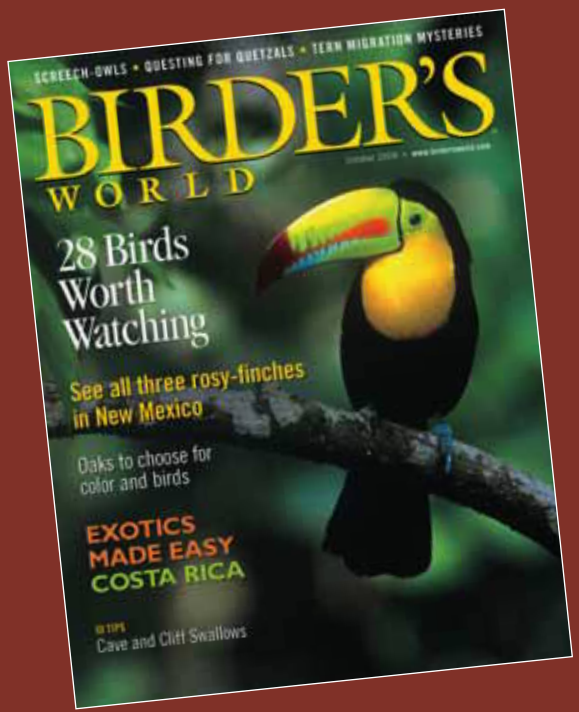
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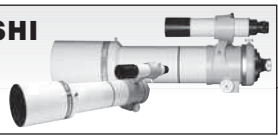

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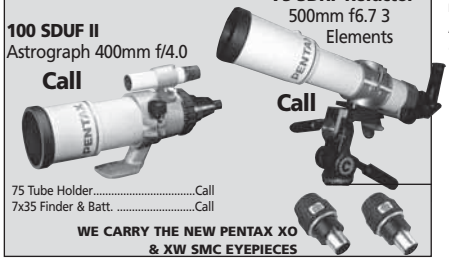

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The advanced section takes a more academic approach to projects. Participants will conduct research, with the possibility of their results being published in professional astronomical journals.

The program also offers camps for teachers and beginning and advanced teens.

To find dates of subsequent camps or for more information, call Don McCarthy at 520.621.4079; fax, 520.621.9843; e-mail, dmccarthy@as.arizona.edu; web site, *www.astronomycamp.org*.

MAY 3, 2005

Asteroids, Meteorites, and Why Science Matters

Santa Barbara Museum of Natural History, Santa Barbara, California. Dale Lowdermilk, a meteorite expert, will discuss a variety of astronomical and geological topics and provide a hands-on display containing meteorites. Part of an ongoing celebration of the reopening of the museum's planetarium, every 20th person entering the lecture will receive a small meteorite fragment. For more information, call 805.682.4711; web site, *www.sbnature.org*.

MAY 4–8, 2005

Desert Sunset Star Party

Caballo Loco Ranch RV Park, near Tucson, Arizona. The Whipple Observatory will offer a day-long tour the Friday during the star party. For more information, visit *chartmarker.tripod.com/sunset.htm*.

MAY 5–8, 2005

Frozen Banana Star Party

Munro Park, near Powassan, Ontario, Canada. Sponsored by the Sudbury Astronomy Club, this is a biannual event, with the other gathering held in autumn. Attendees will be treated to observing

under a dark sky, as well as banana dishes and banana-themed surprises. For more information, e-mail Harold Healy at hhealy@sympatico.ca; web site, *www.sudburyastronomyclub.com*.

MAY 5–8, 2005

International Telescope Meeting Vogelsberg

Feldatal-Stumpertenrod, Germany. Featuring observing, telescope-making, and lectures, this popular event draws hundreds of astronomy aficionados each year. For more information, visit *www.teleskoptreffen.de/itv*.

MAY 14, 2005

Lake Hudson Star Party

Lake Hudson State Park, outside Jackson, Michigan. Sponsored by the Amateur Astronomers of Jackson, this event commemorates the creation of the nation's first dark-sky preserve within a state park. For more information, visit *aaoj.homestead.com/files/aaoj.htm*.

MAY 19–22, 2005

International Space Development Conference

Washington, D.C. Titled "Your Ticket to Space," this conference has sessions that will address various issues affecting space science, technology, policy, commerce, and exploration. For more information, visit *isdc.nss.org/2005*.

MAY 20–23, 2005

Royal Astronomical Society of Canada General Assembly

Okanagan University College, Kelowna, British Columbia. This event will feature a tour of the Dominion Radio Astrophysical Observatory and lectures by leading figures in astronomy, including space-telescope scientist Jaymie Matthews. For more information, visit *www.ocrasc.ca/ga.html*.

MAY 27–29, 2005

Riverside Telescope Makers Convention

YMCA Camp Oakes, near Big Bear City, California. The high-altitude site is located in the San Bernardino mountains. This year's theme is "The History of Astronomy." For more information, visit *www.rtmcastronomyexpo.org*.

JUNE 2–6, 2005

Cherry Springs Star Party

Cherry Springs State Park, Galeton, Pennsylvania. The Astronomical Society of Harrisburg celebrates its 50th anniversary with this star party. While the region features sites with darker skies, none possesses the camper amenities found at Cherry Springs. For more information, visit *www.cherrysprings.org*.

JUNE 2–5, 2005

Wisconsin Observers Weekend

Hartman Creek State Park, Waupaca, Wisconsin. Hosted by the Northeast Wisconsin Stargazers, all five group campsites are reserved, preventing light-pollution instrusion from other campers in the park. Registration ends May 18 and is limited to 150 attendees. For more information, visit *www.new-star.org*.

JUNE 3–6, 2005

Jersey Starquest

Hope Conference Center, Hope, New Jersey. This event will feature lectures, workshops, exhibits, a deep-sky challenge, and door prizes for adults and children. For more information, visit *www.princetonastronomy.org*.

JUNE 3–6, 2005

North Dakota Star Party

Cross Ranch State Park, near Hensler, North Dakota. This gathering is the first major and largest star party in North Dakota in 2005. Activities include observing, lectures, and workshops. For more information, visit *www.und.edu/org/nsas*.

CONTACT INFORMATION

Please submit club announcements 4 months in advance to Coming Events, *Astronomy*, P.O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Also use this e-mail address to submit your events for our on-line calendar.

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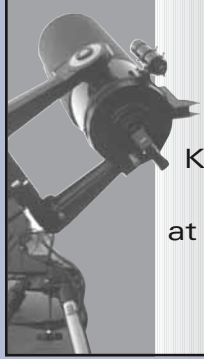
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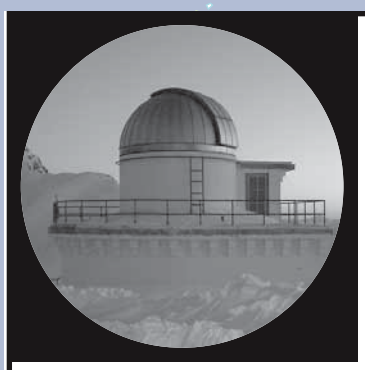

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Comet Machholz /// NGC 3521 /// Lunar halo /// NGC 2774 /// The Pencil Nebula
Jupiter, Venus, the Moon, and Mars /// The Moon occults Jupiter /// IC 1318

COLD-WEATHER SPECTACLE

Comet Machholz

Most observers would be happy to discover just one comet. American amateur astronomer Don Machholz has found 10.

His latest find was a fine binocular sight this past winter. But the comet wasn't bright when Machholz found it. Using a 6-inch Newtonian reflector, he'd been searching the early-morning sky August 27, 2004, when he found a fuzzy, 11th-magnitude object in Eridanus the River.

This photograph shows the standard parts of Machholz's most recent comet: the head, coma, and tail, which — because of the solar wind — points away from the Sun to the upper right. To the lower right of the head is the anti-tail — particles left along the comet's orbit that are too heavy for the solar wind to move.

COMET C/2004 Q2 (MACHHOLZ) (150mm lens at f/5.6 on a driven, equatorial mount, DTA Scientific Instruments Chroma CX3 CCD camera with the KAF 6303E CCD chip, Astrodon filters, LRGB image with exposures of 15, 9, 9, and 9 minutes, respectively, taken January 1, 2005, at 21h30m UT from Cimini Astronomical Observatory near Viterbo, Italy) /// PAOLO CANDY

Top, SPIRAL GALAXY NGC 3521 (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.4, CCD camera, LRGB image with exposures of 90, 20, 20, and 20 minutes, respectively) /// MIKE O'CONNOR, TRISTAN DILAPO, AND GARY KELICH/ADAM BLOCK/NOAO/AURA/NSF

Bottom left, COMET C/2004 Q2 (MACHHOLZ) (2.4-inch Takahashi FS-60C refractor, DTA Scientific Instruments Chroma CX3 CCD camera, Astrodon filters, LRGB image with exposures of 15, 12, 12, and 12 minutes, respectively, taken December 19, 2004, near Viterbo, Italy) /// PAOLO CANDY

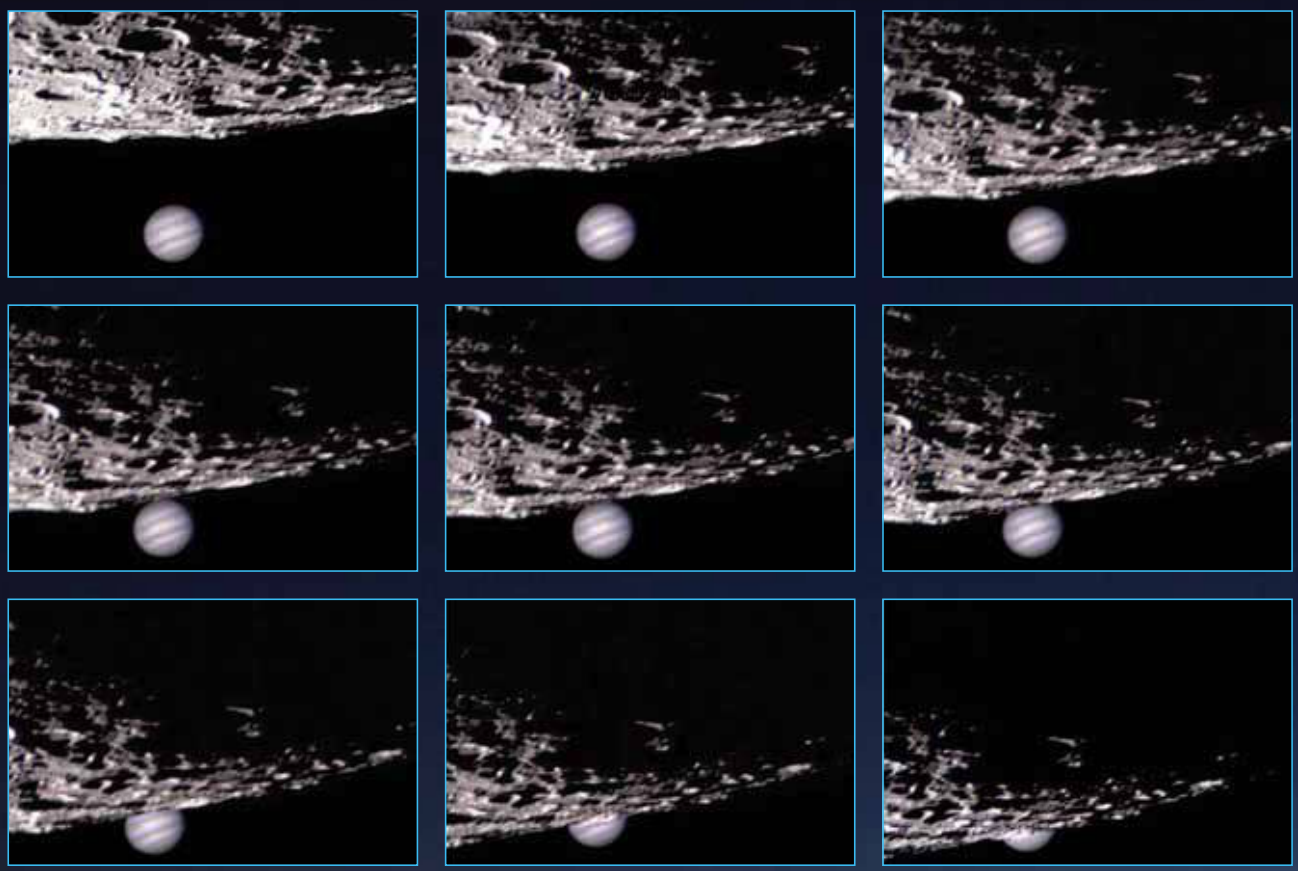
Bottom right, COMET C/2004 Q2 (MACHHOLZ) (4-inch Borg 101 apochromatic refractor at f/6.3, Canon EOS Rebel digital SLR, 25-minute exposure, taken December 14, 2004) /// JACK NEWTON

Top, LUNAR HALO (Canon EOS 20D digital SLR, 20mm lens at f/2.8, ISO 400 setting, mosaic of two 3-second exposures, taken January 21, 2005, from Rossville, Tennessee) /// RONNIE WARNER

Bottom, NGC 2774 IN CANCER (6-inch Takahashi FCT-150 apochromatic refractor at f/7, modified Canon 20D digital SLR, 5-minute exposure at ISO 1600 setting) /// MARK HANSON

Send your photos to: ASTRONOMY reader gallery, P.O. Box 1612, Waukesha, WI 53187; e-mail to readergallery@astronomy.com.
Please include your full name, date and location of image, and complete photo data: telescope, camera, film, and exposure information.

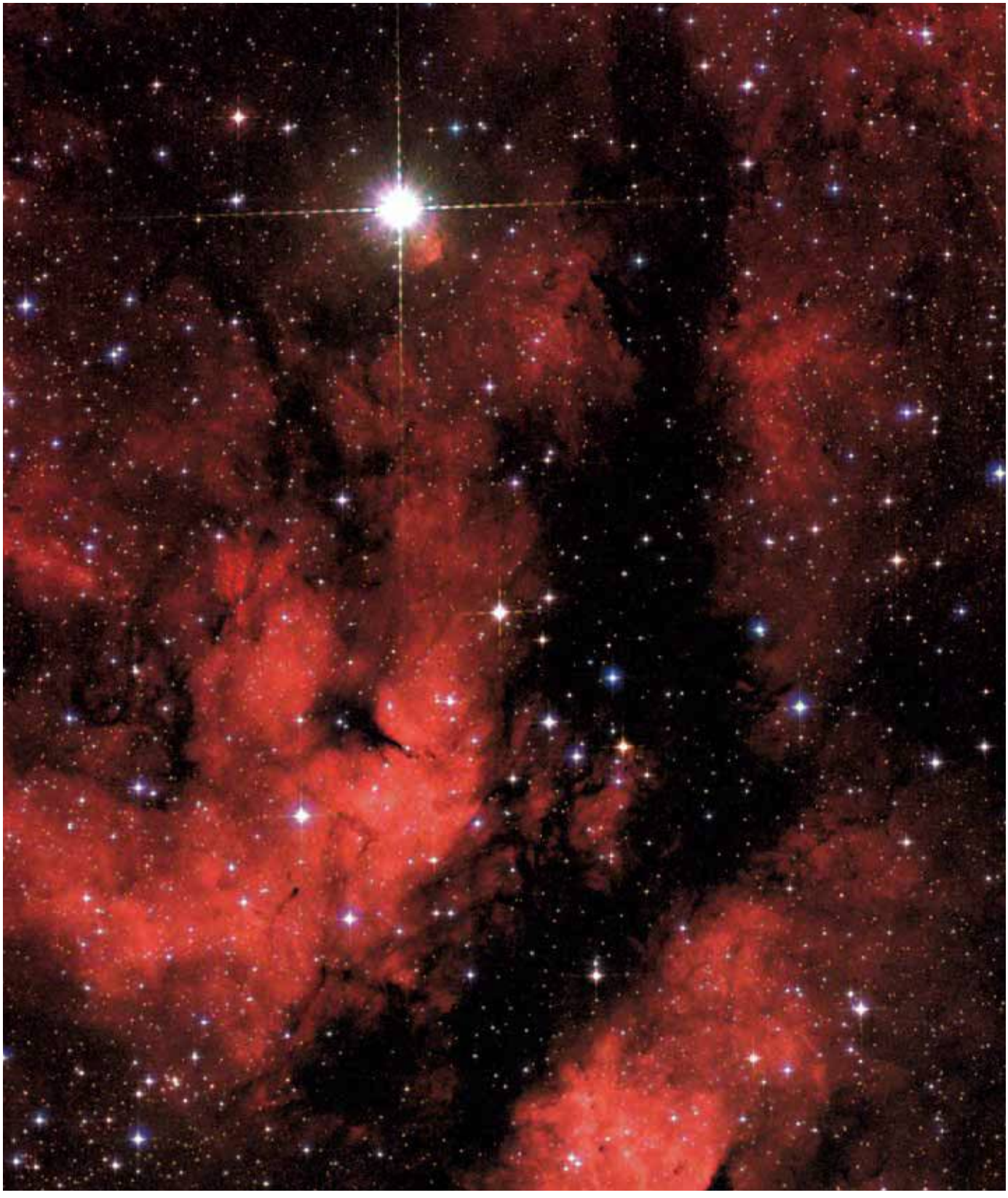
THE PENCIL NEBULA (NGC 2736) IN VELA (14½-inch RC Optical Systems Ritchey-Chrétien telescope at f/6.56, SBIG ST-10XE CCD camera, LRGB image with exposures of 180, 60, 90, and 120 minutes, respectively) /// DANIEL VERSCHATSE



Above, THE MOON OCCULTS JUPITER (10-inch Takahashi Mewlon 250 reflector at f/12, ToUcam Pro webcam, each image comprises 22 frames, taken December 7, 2004, between 9h11m UT and 9h16m UT) /// DONALD PARKER

Background from top, JUPITER, VENUS, THE MOON, AND MARS, WITH SPICA TO LOWER RIGHT OF MOON (Canon EOS Rebel digital SLR, tripod-mounted, 18–55mm Canon lens, taken November 10, 2004, from Garden City Beach, South Carolina) /// STEVE ELLWOOD

EMISSION NEBULA IC 1318 IN CYGNUS (8-inch Celestron Schmidt-Cassegrain telescope at f/6.3, Starlight Xpress SXV H9 CCD camera, Hα/RGB image with exposures of 100, 20, 20, and 20 minutes, respectively) /// WOLFGANG PROMPER



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Meade 10" LX200™ at f/3.5 in equatorial mode, 100 frames x 15 seconds.

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"I admit that when I purchased Meade's new Deep Sky Imager I was more than a little skeptical. I was hoping for success, but preparing for frustration. When I saw the advertisement for Meade's new Deep Sky Imager I was lured by the promise of beautiful images at a non-astronomical price. I was one of the first to purchase the DSI and let me say that, "I'm sold!" I was able to capture incredible images my first night out with my Meade 10" LX200. I imaged M33 in 15 seconds. I could even see the nucleus on the screen in *live mode*. The rest of the night I let AutoStar find dozens of objects, some I had never seen before. Like most people I live close to an urban center. On the very best of nights only a pale smudge hints at the location of the Milky Way. The DSI allows me now to image objects like the Dumbell and Ring nebulas in real time - large and in color right from my backyard. Deep sky imaging is finally easy and affordable. The DSI has reignited my passion for astronomy."

– Peter W. O'Brien
Derry, NH

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